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EDITORIAL.

NOTICE.—The publication of the JOURNAL is made under the direction of the Editor and the Committee of Publication, who endeavor to exercise such supervision of its articles, as will prevent the inculcation of errors or the advocacy of special interests, and will produce an instructive and entertaining periodical; but it must be recognized that the Franklin Institute is not responsible, as a body, for the statements and opinions advanced in its pages.

The United States International Exhibition of 1876.—The prominent event of the past month in the annals of Science and the Mechanic Arts, has been the closing of the Centennial Exhibition, which occurred on the 10th.

The ceremony of closing wanted the imposing character of that which accompanied the opening; but even a larger concourse of people were upon the ground (115,000 were stated to be present). A continued rain prevented the collection of an audience which was to have been comprised of Commissioners and Judges, and officers of the Exhibition, with numerous especially invited guests—arrangements having been made to accommodate, within hearing distance of the speakers, about 10,000 persons, in the same way that this number participated in the opening—but the storm caused the substitution of the Judges' Hall, where, in the presence of about 1,500 spectators (who attempted to listen to the closing congratulatory

addresses), the President of the United States, at 4 o'clock in the afternoon, declared the final closing of the Exhibition, and gave at the instant the signal for the motion of the machinery to cease.

Of the success which has attended the Exhibition in its inception, in each stage of its existence, in its closing scene, at once financially and in good feeling, its excellence in display and in entertainment, in the satisfaction it has given to exhibitors and to visitors, and, not less than all, in the gratification afforded not only to Philadelphia, but to the country, and also of those foreign nations who so generously aided—of the success of the Centennial Exhibition in all these points, there is but one acclamation.

In the remarks which were made (in the JOURNAL, Vol. CI, p. 361), to record the opening of the Exhibition on the 10th of May, it was anticipated that the *novelties* in the mechanical department, of process or production, which were attractive to the general observer, or would have possessed interest to the popular reader, would prove very infrequent. The most careful seeking of the numerous popular magazines and newspapers, whether published here or abroad, has failed to provide for their readers any large number of brilliant or even entertaining descriptions or illustrations; while the higher technical periodicals have had recourse to historical information to supplement the subjects they have undertaken to describe. It is an undoubted fact that the great attraction of all classes at this Exhibition, has been the artistic display. Pictures, statuary, vases, jewelry and carvings, decorations, laces, ornamental wares of all kinds, called for crowds of spectators; while even in the machinery exhibit, except the common shows of water fountains, fancy weaving, fancy wood-sawing, pretty mechanisms of various kinds, always attractive to spectators of all ages, only walking, unobservant throngs were to be seen. It is not that these minor exhibits grouped together, and that the interested throng of persons is not a pleasant spectacle, but what is to the purpose for the editor of a mechanical and engineering journal, is that they do not afford material for his columns.

As was asserted in the editorial before referred to, many of the novelties which became within a brief time prominently notorious to the visitors of the Exhibition, were by no means noteworthy. Trivial shows and productions were rewarded by popular attention to the utmost. The crowd sought entertainment rather than instruction, and in the mechanical devices, found it in anything to wonder at, rather than in anything to be studied, comprehended and

learned. The same taste for surprises in an individual experience, in visiting and examining for one's self, is carried to the gratification to be derived from descriptions of what was to be seen; so that the general writer whose sole purpose is to interest his readers in a magazine account was able at all times to produce an entertaining article, where the careful observer would be unable to discover in the objects on exhibition, much of either novelty or merit—certainly little of either which would be instructive to the practical man.

But aside from these minor displays, there was a very large and satisfactory exhibit of all kinds of working machines in general use—engines, machine tools, saw mills, agricultural machinery, etc., etc.; although the absence of machinery of special manufacturers was even more marked than in any previous international exhibitions. But this exhibit as a very general rule was comprised, so far as it posessed excellence, of the current articles of sale—articles well known to most technical readers, and such as had been repeatedly exhibited and described; upon which, if any improvements did exist, none but those conversant with the particular applications would discern them; they were so completely improvements of detail—while the improvements, when detected, were found to be mere special applications of well known devices, possessing little interest except to the very few who employed the machinery as a matter of business. The opinion was expressed that the examination of the judges would bring out the most striking novelties in mechanism, but this expectation has been frustrated by the action which has awarded prizes to all. And it is to be regretted that no means have been otherwise provided for giving publicity or award for especial merit.

Possibly relief of responsibility on the part of the Judges and of the Commissioners, and possibly, also, good feeling on the part of the exhibitors, have been promoted by the system of seeking for something commendable in every exhibit and awarding a bronze medal for it; but in the procedure, both the judicial character of the judge and the intrinsic value of the prize has disappeared. This general distribution and establishment of level of merit will scarcely meet the approval of even those competitors whose exhibits were below the standard of award, whereon the exhibition, or common usage, may have created a standard. It is a prize and not a commendation that all competitors seek. Much of the outcry against the partiality, unfairness or absolute injustice of the awards at previous exhibitions, is well known

to be mere advertising of commodities,—the pure seeking for notoriety by appeal to the public by printed circulars and through notices in the newspapers. It has been found safer to abuse the judges than to depreciate the value of a competitor's wares, in the legal point of view of the two transactions.

The race will have its excitement and be thronged with competitors, although it be not for the swift. If it had been generally known that no prizes for comparative excellence or novelty were to be given, it is very doubtful if even national or sectional pride would have filled the halls of exhibition. Throughout those miles of passages every object of display was there, not alone for admiration, but for comparison, for selection. What was beautiful to the eye, grotesque to call for observation, farcical to be laughed at, easy to comprehend, crowds found out and enjoyed in a general way; but that appreciation which recognized what constituted excellence in thus producing enjoyment; and more than all this, the appreciation of what constituted excellence and merit in those exhibits which are not merely prettinesses, belonged to competent judges in the several and multifarious branches of science and the arts. The declaration of the result of comparison was one of the obligations of the management of the Exhibition, and the failure to give such a declaration in the form of capital prizes is a disappointment both to the public and to the competitors. Without such prizes great exhibitions lose much, if not most, of their value as means of advancing science and the arts.

Anthracite Coke.—A small specimen of anthracite coke has been given the editor by Doct. C. M. Cresson. It is said to have been coked near Pittsburg from equal parts of anthracite and bituminous dust or slack. The density is about 0·85 and the light spongy aggregation much resembles gas coke in texture, but with more bright grains of unchanged anthracite particles. Its strength is not great, and it is somewhat uncertain if it would bear transportation better than most gas coke does, and consequently it would be found profitable, if not necessary, to make the coke at the works where it is to be used as fuel.

Doct. Cresson's test of this coke gave :

Ash, ...	17·6	per cent.
Sulphur, ...	0·2466	"

and a heating power of 8·08 pounds of water evaporated per pound of coal.

Franklin Institute.

HALL OF THE INSTITUTE, Nov. 15, 1876.

The stated meeting was called to order at 8 o'clock P. M., the President, Dr. R. E. Rogers, in the chair.

There were present 110 members and 7 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and reported that at the last meeting 19 persons were elected members of the Institute; that the award of the Scott Legacy Premium and Medal were awarded to Messrs. Chambers, Bros. & Co., for their Brick-making Machine; and that the following donations were made to the Library:

Outline history of Japanese education prepared for the Philadelphia International exhibition, 1876, by the Japanese Department of Education. New York, 1876. From D. Murray, Commissioner.

Meylert's rational method of drying and preserving food. From A. P. Meylert, M.D.

The Russian system of shop-work instruction for engineers and machinists. Read before the Mass. Institute of Technology, Aug. 21, 1876, by J. D. Kunkle. From the Author.

Report on the Twelfth exhibition of the Massachusetts charitable mechanic association, Boston, Sept. and Oct., 1874. From the Association.

French metric system of weights and measures, by J. W. Nystrom, C.E. From the Author.

On the state of the Iron Manufacture in Sweden at the beginning of 1876. From S. Westergood.

Norwegian special catalogue for the international exhibition at Philadelphia, 1876. Christiania, 1876. From the Norwegian Department.

Jetty System, explained by Jas. B. Eads, St. Louis, 1874. Report on the Mississippi Jetties, by Jas. B. Eads, Chief Engineer, Aug. 18, 1876. Letter from J. B. Eads to the Secretary of War, with Appendices. New Orleans, 1876. Physics and hydraulics of the Mississippi river, Report of the U. S. Levee commission, reviewed by Jas. B. Eads, C.E., St. Louis, Feb. 19, 1876, New Orleans, 1876. From Jas. B. Eads.

Antique Jewelry and its revival, by Signor Alessandro Castellani (of Rome). From J. H. Coates, publisher, Philada.

Science made easy; a series of familiar lectures on the elements of Scientific Knowledge most required in daily life, &c., &c., by Thos. Twining. London, 1876. From Chapman & Hall, publishers.

Seventh annual report of the Geological survey of Indiana, made during the year 1875, by E. T. Cox, State Geologist. Indianapolis, 1876. From E. T. Cox.

Mittheilungen der K.k. Geographischen Gesellschaft in Wien, 1875. XVIII. Band (der neuen Folge VIII). Wien, 1875. From the Society.

Lawrence Water Works. Reports on the trial of duty and capacity of the pumping engines, May, 1876. From E. D. Leavitt, Jr.

History, manners and customs of the Indian nations, who once inhabited Pennsylvania and neighboring states, by Rev. John Heckewelder, &c. Philada., 1876. From the Historical Society of Penna.

De la transmission et de la distribution des forces motrices a grande distance, par A. Achard. Paris, 1876. From the Author.

Specifications and drawings of patents issued from the United States patent office for May, 1876. From the Patent office.

South Australia: Its history, resources, and productions, edited by Wm. Harcus, Esq. London, 1876. From S. Davenport, Centennial Commissioner.

Geological survey of Kentucky: Chemical examinations of ashes of Hemp and Buckwheat plants, with remarks, &c., &c By Robert Peter, M. D., Chemist to the survey. Pt. 3, Vol. 2, 2d series. From Robt. Peter, M. D.

Instructions to Observer-Sergeants, Signal service, U. S. A., on duty at stations. Washington, 1875. Practical use of meteorological reports and weather maps. Washington, 1871. War Dept. weather map signal service, U. S. A., for Oct., 1873, and January—December of any year. From Albert J. Meyer, Brig. Genl. and Chief Signal Officer U. S. A.

Les Promenades de Paris, Bois de Boulogne, Bois de Vincennes, Parcs, Squares, Boulevards, par A. Alphaud. Paris, 1867–1873. From Dr. Chas. M. Cresson.

The Secretary presented his Report, embracing Mr. T. J. Lovegrove's new Boiler Tube expander; Saml. L. Harrison's car axle for turning curves without friction; Dr. A. P. Meylert's apparatus for drying and preserving food; Saml. Murset's Fire Escape; and a governor for the prevention of racing in marine engines, the invention of Mr. A. Adamson, Past Asst. Eng., U. S. N.

Mr. Robt. Briggs gave an illustrated description of Hipp's chronograph, prefacing it with a short paper on the general subject of divisions of time.

The Secretary gave notice that the catalogue of the library is now complete, and is for sale, bound in cloth, at $2.00 per copy. He also again called the attention of members to the elementary series of lectures, which commence on to-morrow evening, and urged members to do all in their power to secure the attendance of those intended to be benefited, and to encourage such persons by coming themselves.

Under the head of deferred business was taken up the motion of Mr. Jones, relative to the Majority Report on the metric system of weights and measures, the original motion having been divided into three separate resolutions, as follows:

1*st*, *Resolved;* That the Reports of the majority of the committee on the subject of the metric system of weights and measures be adopted.

2*d*, *Resolved;* That a copy of the same be transmitted to the Boston Society of Civil Engineers.

3*d*, *Resolved;* That the Report of both the majority and of the minority of the committee be printed in the JOURNAL.

The general subject was discussed by Messrs. Orr, Briggs and Tatham, when Mr. Briggs moved to lay the whole subject on the table, which was lost.

After considerable discussion the previous question was called, and sustained by a standing vote of 39 ayes to 31 nays.

The Chair then put the first resolution, and it was adopted by a standing vote of 41 ayes to 39 nays.

The second resolution was also adopted.

The mover stated that as both reports have already been published in the JOURNAL,* by authority of the Committee on Publication, it was not necessary that the third resolution should be adopted; and on putting it to vote it was lost.

The proposed amendment to Sec. 2 of Act VII of the By-laws, offered by Mr. J. J. Weaver, and postponed from the last meeting, was then taken up, and was discussed by a number of members.

The previous question was called and sustained.

The question of the adoption of the proposed amendment being put to vote, it was lost.

On motion, the meeting adjourned.

J. B. KNIGHT, *Secretary.*

* See Vol. ci, pp. 870–884. June, 1876.

Tube Expanding.—The tube expander of Mr. T. J. Lovegrove, exhibited by the Secretary at the meeting of the Institute, is remarkable as a novel use of the elasticity of form of india rubber. The expander is simply a ring or collar of india rubber, fitting closely upon a bolt of iron and secured between two discs, inserted in the end of the tube to be set or expanded, and held or clamped firmly in place. This collar is then compressed, in the direction of its length, by means of a screw on the bolt, which moves one of the discs, and the effect of this endwise compression is to expand the rubber ring in radial direction, producing a hydrostatic pressure on the inside of the end of the tube, proportionate, and almost equal in value, or amount, to the endwise pressure exerted by the action of the screw on any unit of surface of the rubber collar. This result proceeds from the fact that, while rubber has much elasticity of form, it is almost wholly incompressible in volume. In fact it is one of the most incompressible solids known, if not *the* most incompressible. It very closely approaches to water in this regard, and seems to be devoid of either pores, or particle elasticity, which pertains to other solid bodies however composed. (It is probable that all liquids in common with water are incompressible except in some slight degree.) The idea of taking advantage of this quality of rubber for obtaining a hydrostatic pressure, while its tenacity prevents its escape, or flowing away, at the joint between the discs and the inside of the tube, is decidedly novel, and is thought to be original with Mr. Lovegrove.

Flooding of the Thames Tunnel.*—Underground railways in the metropolis are all liable to be flooded with water, and to prevent this, continuous pumping in certain districts is required. For example, on the Metropolitan District Railway, steam pumps are in operation night and day, at the Victoria and Temple stations. The East London Railway is no exception to the rule, and owing to the failure of the pumping machinery at Deptford-road, the line has been rendered impassable for a few days. The facts appear to be as follows:—On Monday morning, at the Deptford station, it was discovered that water was percolating through the gravel from the new dock of the Surrey Commercial Company on to the permanent way. The inflow was not a large one, but the pumps at Deptford-road,

* From *The Engineer*, London, October 27th, 1876.

which, in order, would have been able to cope with it, were in such a state of disrepair as to be useless. From Deptford-road station there is a rather steep gradient to Rotherhithe, where the Thames tunnel commences. There is a similar rise from Wapping towards Shadwell, so that the tunnel being the lowest part of the line, and the flow of water being unchecked, it soon rose to such a height between Wapping and Rotherhithe that is was deemed advisable to stop the through traffic. There are pumps at Rotherhithe as well as at Deptford-road, and the former would have been quite sufficient to keep out the water, but they, like those at the latter place, happened to be out of order, and after being at work for a little time they broke down altogether. Through traffic was suspended at 11.20 on Monday morning, but the tunnel pumps, though out of order, were able to reduce the height of the water by night, so that the two last trains were taken through; but soon afterwards the tunnel pumps became unfit for further service without repairs. These repairs are now being carried out, so that in the opinion of the railway officials the resumption of the traffic depends upon the time it will take to place them and the others at Deptford in order. The rumor that the crown of the tunnel beneath the London Docks had given way is untrue; in fact, the trains have been running beneath the basin to and from Wapping, and on the other side of the river between Rotherhithe and New Cross, ever since the stoppage of through traffic, and as if that check had never taken place. It will be remembered that the line runs close to the new Surrey Commercial Dock. This dock was partly filled ten days ago. What will happen to the railway when it is quite filled remains to be seen. According to the latest reports the line had been cleared for the present.

Grindstones.—None of the processes of the mechanic, however commonplace they may seem, are below the universal law of being required to be learned. Either practice or instruction must teach the beginner; intuitive mechanics, who trust to their own experience, are likely to have a deal of it, before they attain a capability that is trustworthy in any branch. A little pamphlet on grindstones and grindstone fixtures, issued by J. E. Mitchell, of this city, as an accompaniment to an advertising exhibit at the Centennial Exhibition, is a striking exemplification of the desirableness of a *literature* on a special subject. Our grindstones come from England, from

Scotland, from Nova Scotia, from New Brunswick, from Ohio, from Michigan. They are found in the sand rocks of different ages—they are suited to various uses—they must have special treatment to render them valuable for particular requirements. It is as much of an art to run a grindstone for any purpose as that of the smith, the machinist or the plumber, and the occasional use of a stone by other mechanics, presents to them as many difficulties as the taking up of another trade, which mechanical engineering sometimes requires. It is the ability to makeshift in case of necessity that makes at once a skilful and skilled workman.

Mr. Mitchell's instructions as to how to hang a stone, how to keep it in order, how to keep it from getting out of order, are the result of a lifetime of knowledge of the *experience* of those whose neglect, ignorance or conceit has found out the what to do and what not to do with a grindstone. It is stated that they should always be hung by plates which clamp the sides of the stones, in lieu of being keyed and driven by a square hole in the centre,—that they should be turned all over to run true,—should be abundantly supplied with water when grinding, but never permitted to stand in water when not running. That large stones should be kept true by the free use of the hacker, and small ones by the constant use of the turning tool. The bresting of grindstones is attributed generally to the allowing a part to stand in water when not in use. Great care should be exercised in examining a stone for defects before hanging it. The sides and edge should be washed off with water and a broom, and if any crack be discovered, the stone should be rejected.

The use of the grinding processes in the machine shop is rapidly increasing. Rolling, stamping or squeezing metal into shape, and to exact size, without calling for the planing, or turning, or milling operations, are practices of great economic value in mechanism. Cutlery of all kinds, knives, forks, scissors, scythes, besides many parts of engines and other machines, are forged to exact dimensions, and the emery wheel, or the grindstone and hone, gives the finish. Work made in this way is really better than that which has been wrought out of the solid. As the grindstone is the important element in this kind of workmanship, a reference to Mr. Mitchell's pamphlet is one of the best ways to learn "how to use a grindstone."

TOUGHENED GLASS:

NOTES ON ITS MANUFACTURE.*

From *The Practical Magazine* of London, for October, 1876.

The following notes on the manufacture of toughened glass are the result of a visit to the factory at Choisy-le-Roi by M. Bourée. The process employed is that of De la Bastie. M. Bourée says that the result of the hardness of the glass being above all things a question of care, he enters into the details, it may seem, somewhat minutely; but he thinks it necessary in one who wishes to give an exact account of the process.

Theory of Toughness.—Toughness is a quality obtained by suddenly cooling a body after it has been heated. Glass is toughened by immersing it when red hot in a bath of a given temperature; that is to say, the glass, after having received its definite shape, instead of being placed in an oven where it gradually cools, after having gone through the operation of annealing, is, on the contrary, again heated to redness and rapidly plunged into a bath of grease. The toughness is the more effective in proportion to the excessiveness of the heat and the rapidity of the cooling. The cooling is obtained by the difference of the temperature of the glass at the moment of immersion and that of the bath. The effects of the toughening are purely physical. The toughening changes the molecular composition of the glass; it becomes less dense, and its fragments, when it is broken, do not contain sharp edges like ordinary glass. Pressed into the flesh it does not wound. This phenomenal metamorphosis will be accomplished under the better conditions the less of cohesion there is between the molecules. The more glass is malleable and approaches a pasty state, the more the molecules are easily displaced to group themselves after a certain law. Glass that has not been brought to a sufficient degree of malleability will be imperfectly toughened, and below a certain temperature will be insensible to the action of the bath; but if too soft it will be distorted. The glass to be submitted to the toughening process should be heated to a temperature approaching that which would alter its shape—

* It should be borne in mind that the degrees of temperature referred to in this article are Centigrade—0° = 32° Fahrenheit. The word "toughened" is here employed, notwithstanding its possible faults of construction, as it has been adopted in this country as a denomination of the peculiar manufacture.

nearly to melting. The more effectual the cooling the greater degree of toughness is attained; but the toughened glass breaks in a bath the temperature of which is too low. The reaction is too precipitate; the displacement of the molecules is produced in too accentuated a manner, and the equilibrium is broken. Within a certain limit the temperature of the bath is subservient to that of the glass. The minimum temperature of the bath in which the glass, heated to almost melting, is susceptible of being toughened must be found. It is to be found by experimenting, and varies:

1. With the composition of the glass.
2. With the form, the thickness, and the dimensions of the article.
3. With the temperature of the glass.

On the Influence of the Nature of the Glass on Toughening.—In accordance with its composition, glass approaching melting, and passing through its different states of malleability by very variable temperatures, the temperature of the bath should be also varied. Repeated experiments will best show. Primarily, it will be necessary to determine the temperature and the nature of the bath that is the most advisable for glass of which the exact composition is known. It may be said in general, that the bath should be warmer in proportion to the softening of the glass being slower. Crystal: All crystal is toughened in a bath of pure grease in a temperature of from 60° to 120° Centigrade. Trials have been made with Baccarat crystal. A crystal composed of 300 parts of sand, 100 of potash and soda, and 50 of red lead, is one that succeeds well in toughening.

Glass: Glass is toughened in a mixture of oil and grease of a temperature varying from 150° to 300°; the more difficulty in melting the glass the higher the temperature employed. The proportions in which lime and soda enter into the composition notably influence the temperature of the bath. Bohemian glass, having a basis of potash, is toughened in a bath of at least 300°.

The Temperature of Crystal varies with the Thickness and Form of the objects.—Shaped pieces of crystal coming from the same crucible, in accordance with their form, their thickness, and their dimensions, require to be more or less reheated before being treated for toughening. The temperature of the bath should be also varied within certain limits. Thick pieces require to be reheated the most, and want the bath a little hotter. Thus at Choisy-le-Roi gas tubes, lamp glasses, &c., are toughened in a bath of 60°; while drinking glasses and goblets, according to their form and dimensions, are

toughened in baths reaching 60°, 65°, 70° and 75°. Water-bottles, dishes, &c., are toughened in baths varying from 75° to 90°.

Composition of the Bath for Glass and Crystal.—The composition of the bath has a notable influence. All liquids are not appropriate for toughening. In water, glass always breaks. Perfectly pure grease and virgin oil, free from all mixture, give the best results. Pure grease is employed for toughening crystal in preference to oil. Pieces toughened in oil attain clearness at much too great an expense. The toughening of glass requiring a bath of a temperature varying from 150° to 300°, pure grease cannot be employed on account of its ebullition. Recourse is therefore had to a mixture of three-fourths of linseed oil with one-fourth of grease. Pure glycerin, or a mixture of grease and glycerin, that will not boil up to 300°, may be employed with advantage in toughening glass. Toughening cannot be properly accomplished in a bath of grease that is not free from impurities or the least quantity of water. For this reason a new grease should not be employed that has not been previously heated for four or five days to a temperature of 150°. It can be used indefinitely afterwards, and the older it is the better. In a factory there should always be, in a fixed place, a constantly heated vat of grease that would serve to replenish the baths. An indispensable condition for the success of the toughening is that the temperature of the glass should be perfectly uniform on all points of its surface.

Means of Conversion for Table Glass.—Glass irregularly heated breaks in the bath, the toughening not being equal the equilibrium of the molecules is disturbed. In table glass the object leaving the hands of the moulder has a nearly uniform temperature in all the points of its surface; it is always hotter at the extremity last fashioned, and reheats more there. In this state it is not susceptible of receiving toughness; not being warm enough it should be replaced in the working-hole, and as deeply as possible, to insure the equal distribution of heat in all its points. In taking it out, the workman must assure himself, before plunging it in the bath, that this condition is fully realized. If the extreme parts appear redder than the others he will wipe them delicately with a piece of paper slightly wetted, and replace the piece in the working hole for a few seconds before toughening. How long the glass should remain in the oven is for the workman to learn to determine. I will meanwhile say that a good workman toughens better with more heat. That piece which, brought to softening, would be deformed in unskilful hands, preserves,

on the contrary, its form perfectly when confided to a trained toughener. It is important also that the temperature in the working-hole should be uniform. This is attained by heating it by burning wood equally distributed on the surface. Currents of air in the factory, which might cool the glass at the moment of toughening, must be carefully avoided.

(To be continued.)

TIMBER NOMENCLATURE.

[From the *Timber Trades' Journal.*]

[Continued from Vol. cii, page 203.]

Thorn, although generally associated with our cultivated hedges, had in its Anglo-Saxon form a more extended meaning. It implied a tree, although not of the first order. In this sense it is used in the "Buckthorn," and the "Blackthorn." From the study of place-names in Mid England, we are led to infer that thorn implied a wood; a portion of Sherwood Forest was known as "Thorneywood chase," and part of Hatfield chase an extensive wood known as "Thorne-waste." Indeed "Thornhills" and "Woodhills" occur in such order that we are led to the conclusion that they are synonymous terms.

Timber is from the Anglo-Saxon "timber," and "tymber." 1, wood; 2, a tree; 3, a frame structure or a building, From the fact of building being conducted in wood, timbering (*getimbrian*) was the equivalent of building. At the burning of the first wooden church or cathedral at York, in 626, a larger church was ordered to be *getimbrian* of stone. It does not appear to have been a term much used in a territorial sense. Henry II. confirmed the grant of the church of Tymberland to Thurgarton Priory, Notts, which may or may not be the village of that name in Lincolnshire. From this we may infer that the term applied more to the wood in a dead state than to that of the living tree; in which sense it has undergone little or no change.

Tree, from the Anglo-Saxon "treow." 1, a tree; 2, wood; 3, a piece of wood. In the latter sense, it is used in shipbuilding and carpentery, as "cross-tree," "roof-tree," "side-tree," &c. "Treow-wyrhta," the tree or wood worker, was the old term for carpenter be-

fore we borrowed the French one of *charpentier*, and "treow-geweorc," tree work, was the primitive of the now general "woodwork."

Wainscot is a word of doubtful etymology. Bayley says it is from the Belgian "wandschote," wall defence or lining. Ogilvie says it is from the Dutch "wagenschot," which evidently means wagon lining or covering; whereas Loudon says it is from the Dutch "ward," a wall, and "schoten," to suspend. These derivations are evidently sought for, the various authorities having in view the fact of wainscots being largely used in the Tudor and Stuart ages for wall framing or paneling, which appears, probably from being made of oak, to have taken up the name of wainscoting. As wainscots were articles of import centuries before this time, it is highly probable these authors were in error. In the *Liber Albus* of the city of London in the reign of Henry II (1215–1266), we find the following note:—"For every hundred of boards called weynscotte one halfpenny to be paid as custom upon landing at Billingsgate;" and "wainscot" formed items of assessment in the cargoes of nearly every ship arriving in Hull, 2d Henry IV (1400). The writer records these notes to assist in the solution of this knotty term, the accepted derivations of which are in no way satisfactory. It may be further noted that wainscot in the Swedish and German dialects bears the sense or meaning of wall-lining or paneling.

Walnut, a name that occurs with little variation in the German and Swedish dialects, is from the Anglo-Saxon "wealh-knut," the foreign nut. "Wealh" was a term our rude forefathers applied to anything foreign, hence "wealh-men," Welsh-men, the Celtic race formerly inhabiting this country, but driven by them into the fastnesses of the Welsh mountains. The etymology of this word implies that the same people were acquainted with this fruit long before the tree was introduced. Like many other fruit-bearing trees, it is supposed to have been introduced by the Romans, but to have been lost through the neglect they received after the departure of these warlike people, and to have been reintroduced by the monks of the middle ages, who were great gardeners and cultivators.

Wood is a grand old Teutonic term. It is the Anglo-Saxon "wude," German "wald," and the Swedish "ved." It means 1, a tree; 2, the substance of a tree; 3, a collection of trees. "Wude-beam" was the primitive term for forest-tree, and "wood-hewer" and "wood feller" of woodman. The mention of this term reminds us of the Scriptural allusion to "the hewers of wood and the drawers of water."

In early times, the calling of wood-hewer was of that importance that it stood for a family name with the followers thereof; hence the common surnames of Woodyeare, Goodyear, &c.; by the same rule the progenitors of the wood-fellers are recognized under the *nom de plume* of Goodfellow. In a territorial sense, "wood" has given its name to numerous families, some of which may be recognized under the corrupted forms of "Good" and "Hood." Robin Hood, the popular myth of the middle ages, is supposed to be a name or term drawn from his calling—"Robber of the Wood," as robbers were called "Robin-men." "Robin" is given in the "Dictionary of Phrase and Fable," as highwayman. Perhaps one of the most remarkable uses of the term "wood" was in application to timber dealers or merchants, whom we anciently called "Wood-mongers," the equivalent of the Swedish "ved-hanlare." The writer has documentary evidence of the use of this serio-comic term in London as early as 1350, and in Hull as late as 1650.

Wright, the short or abbreviated form of "wroughter," a workman, may in conclusion be noticed. It is curious that it has affixed itself to those trades associated with wood; thus evidencing the former importance of these crafts or callings. We have already noticed that ancient "tree-wright" is buried under the modern term of carpenter, but it lives in cartwright, wheelwright, wainwright, plowright, shipwright, and boatwright, which are common as trade or personal names.—*Wm. Stevenson, F.R.H.S., Hull.*

Book Notice.

The Editor acknowledges the receipt of a pamphlet on "Interpolation, or adjustment of series," by E. L. DeForest, Watertown, Conn., privately published. This pamphlet is a continuation of two other papers on the same subject which appeared in the Annual Reports of the Smithsonian Institute, for 1871 and 1873. In this country the interest in *pure mathematics*, either popularly or professionally, is so little developed, that even the Smithsonian Institute is dilatory in publishing; and the author in this instance, fearing a loss of his reward on an original investigation, has issued the present publication. There is no study so engrossing, and *consequently* so pleasant to the student as *pure mathematics;* and especially as its pursuit calls for a high order of intellectual ability, it is to be regretted that the same interest is not taken here as in foreign countries; as it is, however, we can only call the attention of the few of our readers whom it concerns, to this work, which contains some new and interesting formulæ and applications.

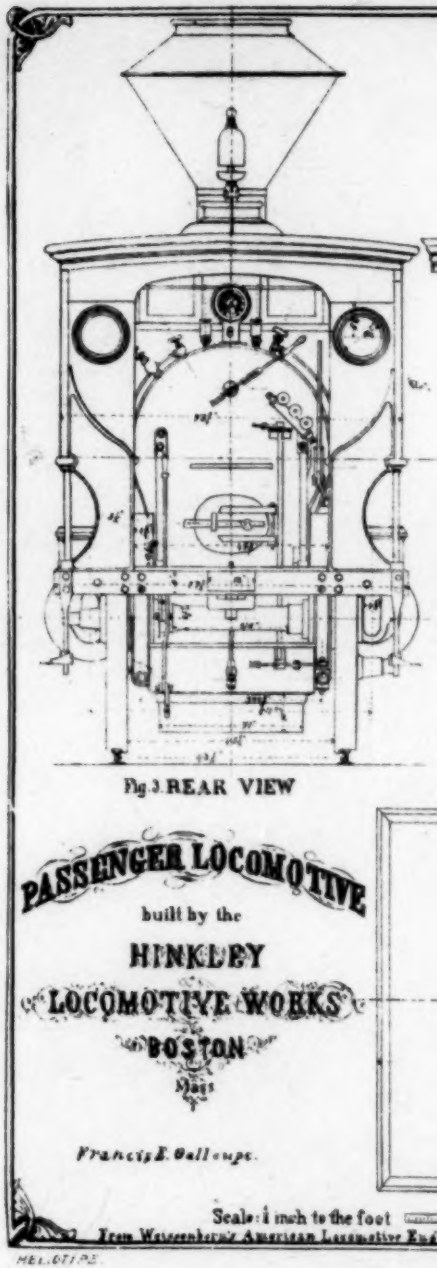

Fig 3. REAR VIEW

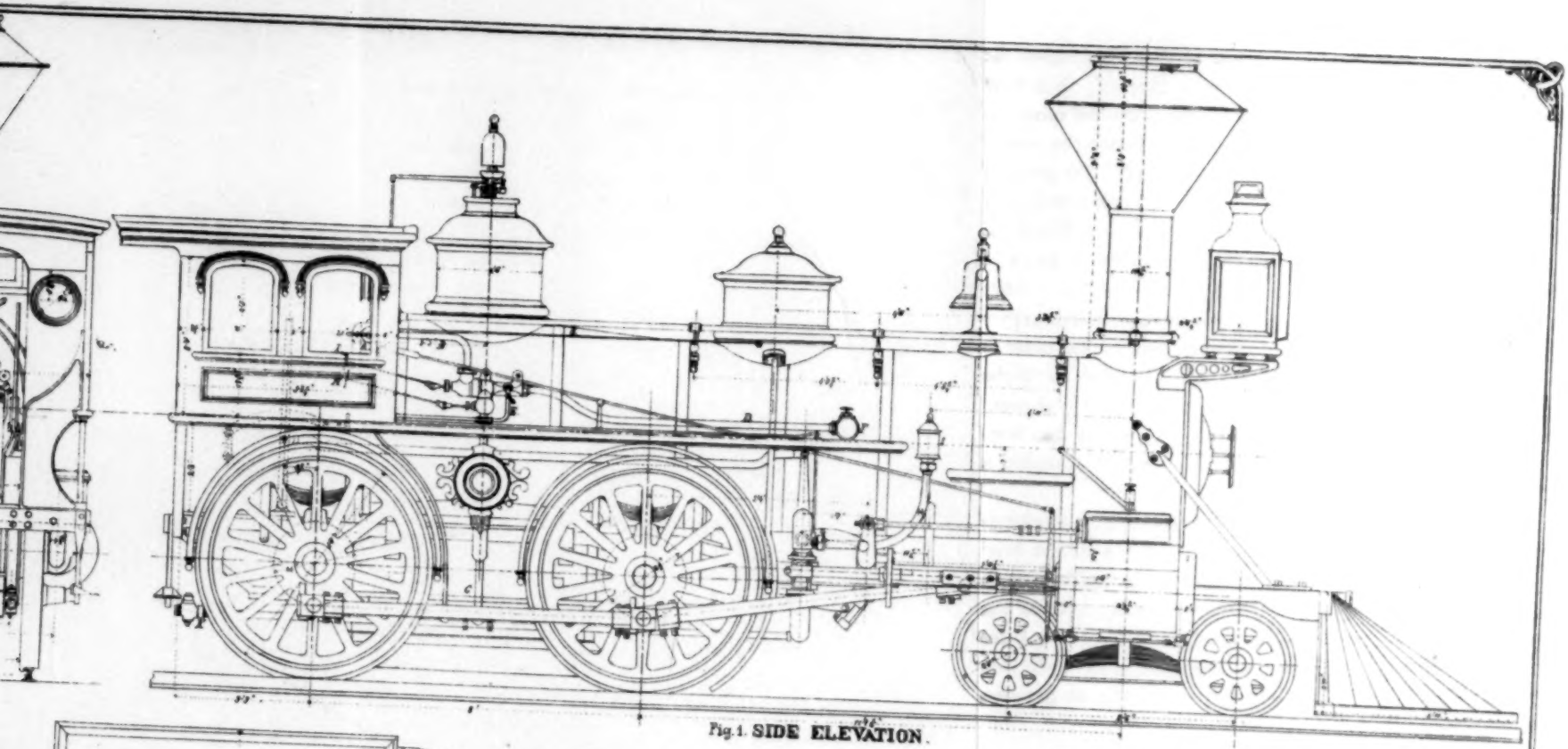

Fig. 1. SIDE ELEVATION.

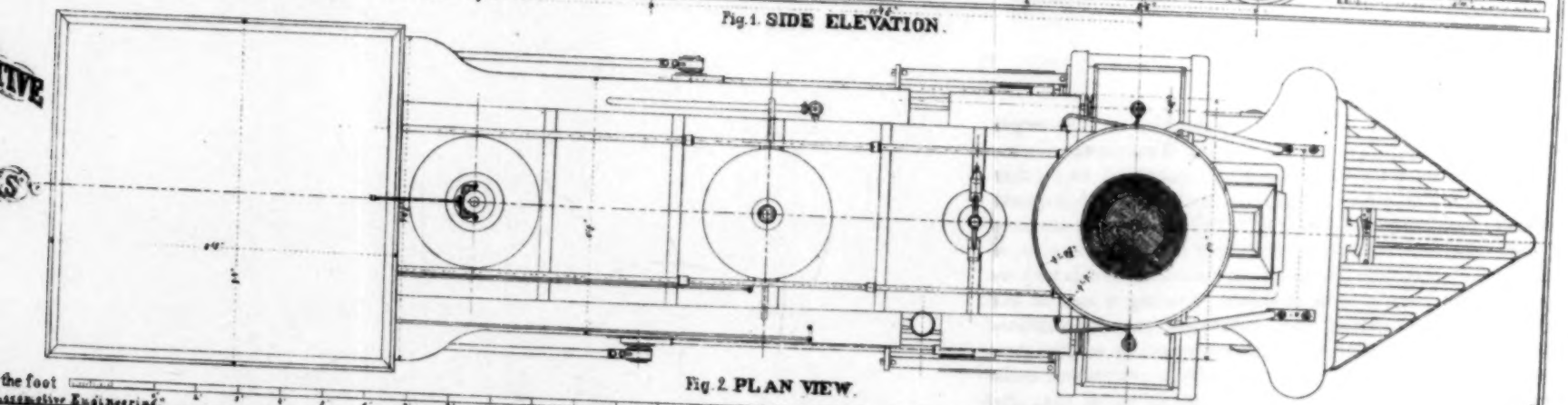

Fig. 2. PLAN VIEW.

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Plate A.

Civil and Mechanical Engineering.

CERTAIN POINTS IN THE DEVELOPMENT AND PRACTICE OF MODERN AMERICAN LOCOMOTIVE ENGINEERING.

By Francis E. Galloupe, S.B.

[A portion* of a Thesis presented for Graduation in the Mechanical Engineering Department of the Massachusetts Institute of Technology, Boston, May 1, 1876.]

Part I.—An American Passenger Locomotive.

"The locomotive engine," it has been said, "may be selected as the grandest and most important development of modern civilization and human skill." It occupies a prominent position, and constitutes a great and important branch in mechanical or dynamical engineering. In it we deal with dynamical science—the science of motion and of power.

The first impression received by even a casual observer, is that of power. Its condition throughout is that of a transmitter and transmutor of energy. It begins in the furnace, with receiving power, as the motion of heat, from the combustion of coal; transmits it to water and steam, as the working fluid, by means of the boiler; and converts it in the engine into visible motion of masses of matter through space.

In a more limited sense the locomotive engine may be defined to be a machine for converting the expansive force of steam into mechanical work. Its ultimate object is to draw a train of a certain number of cars upon a specified maximum ascending grade at a certain velocity. It consists of two high pressure steam engines, mounted upon wheels, and carrying not only the apparatus for

* In a previous portion were considered the subjects of Force, Heat, Combustion of Coal, Water and Steam. Beginning with a historical sketch, the modern theory of the nature of force, motion and heat, the primary moving force in the locomotive, was treated. The heat of combustion and evaporative power of bituminous coal were then calculated, and the efficiency of steam determined under the ordinary conditions in locomotive practice.

generating and distributing its power, but many adjuncts for the convenience and safety of those who run it, and the public at large.

As it now exists it has more than *two hundred* parts in its anatomy alone, each having its distinct work to do, and all so interdependent that if any one fails, it may involve the others in a general destruction.

A complete discussion of the locomotive would, I suppose, include at least the treatment of all of these; but it may be sufficient for the present purpose, to classify its parts as on the opposite page.

The differences in the construction of locomotives have produced different classes, and they have hence been classified in various ways, according to their use and the arrangement of their parts.

With reference to their *parts*, locomotives were formerly divided according to the *number of pairs of driving wheels* that they had; and this has been continued to the present time in the Baldwin Locomotive Works, where those having one pair of driving wheels are called B engines, two pairs C engines, and so on. Another system of classification has been according to the *position of their cylinders*, whether surrounded by the smoke-box or with outside connections, in which all locomotives were either *outside* or *inside connected* engines. The latter class has nearly disappeared from American engines, on account of their requiring the cranked axle, which was expensive; the working parts were also greatly crowded, and other injurious effects produced.

With reference to their *use* or *service*, we may now regard all American locomotives as of the outside cylinder pattern, and classify them as either *passenger*, *freight*, or *shifting*, which latter are often *tank* engines.

There is a sub-variety, which falls mostly under the first of these, called *narrow gauge* engines. Some of these are but a reproduction on a reduced scale of the larger engines. In the real type of narrow gauge engines the peculiarity is a short rigid wheel-base, or distance between the driving wheels. The peculiar construction which admits of this was designed by Mr. Robert Fairlie, in England, and greatly improved upon by Mr. William Mason, of Taunton, Mass. The cylinders, driving wheels, and all the working parts are attached to a frame, which turns about a centre-pin like an ordinary truck. The front part of the boiler is hung upon a vertical link, so that on passing short curves the truck and wheels very closely follow the curvature

CLASSIFICATION OF PARTS.

THE LOCOMOTIVE.

A. The BOILER, or apparatus for generating the power.

I. *The Heating Apparatus.*

1. The Cylindrical Shell.
2. The Furnace.
3. Miscellaneous.

II. *The Feed Apparatus.*

a. The Pump.
b. The Injector.

III. *The Safety Apparatus.*

1. The Safety Valves.
2. The Steam Gauge.

The Air Brake.

IV. *The Transmission Apparatus.*

1. The Throttle Valve.
2. The Steam Pipe.
3. The Exhaust Pipe.

B. The ENGINE, or apparatus for using and converting the power.

I. *The Cylinder and Connections.*

1. The Cylinder.
2. The Cross-Head.
3. The Connecting Rods

III. *The Running Gear.*

1. The Driving Wheels.
2. The Axles and Journals.
3. The Trucks.

II. *The Valve Gear.*

1. The Slide Valve.
2. The Link and Eccentrics.
3. The Reversing Apparatus.

The Framing.

The Tender.

The Tank and Bin.

The Brakes.

of the rails, while the boiler swings over, relatively to the truck, upon the link. These engines, so far as I know, are used almost exclusively for passenger conveyance.

In all engines of the passenger class, in which the maximum speed is wanted, and light loads carried in comparison with the freight, there is a necessity for a long wheel-base to prevent "galloping" or "pitching" of the engine, and in the narrow gauge engines this is effected by a rigid connection between the engine and tender, which, while it lengthens the total wheel-base by an amount equal to the distance between the rear driving wheel and rear tender wheel, does not at all effect their peculiar property of passing around curves of extremely short radius.

In the freight class, great tractive power, and therefore a multiplication of coupled wheels, a small diameter of driving wheels and a consequent low speed, are the distinctive features.

In the shifting class, the tank engines utilize the weight of the water and fuel by supporting it upon the driving wheels, and do not work under the disadvantage of pulling a heavy tender after them. The object is to move light loads for short distances and to start them and attain speed very quickly. They have a short wheel-base which enables them to run over switches and upon sidings of very sharp curvature, and this quality more than compensates for the pitching motion which would result if they were put upon fast passenger trains.

The cost of a modern American passenger locomotive is from $8,500 to $11,000. Its ordinary "life" is ten years. Sometimes an American engine will remain in operation twenty-five years, so great is the difference in the effects produced upon them in different localities, and under different conditions. According to a paper read before the British Association, the life of a locomotive is "thirty years;—boiler tubes, five years; crank axles, six years; tires, boiler and fire-box, seven to ten years; side-frames and axles, thirty years." "The total cost of repairs in that time is $24,450; so that it requires in eleven years a sum equal to its first cost," and the distance it would travel in that time may be taken at 220,000 miles.

The progress in the construction of steam engines has been in three directions,—*land*, or *stationary* steam engines, including the great diversity of examples in pumping engines for water works, and the portable and semi-portable types; *marine* and *locomotive*. Each

class has its distinctive features and conditions, in conformity with which the machine must be designed and under which it must work. In the locomotive, the speed, weight of train and the grade are given, from which to design and build the entire structure in all its intricate parts. The principles by which this is done have not yet, to any great extent, been reduced to formulæ, but the engines have been built by a process entirely empirical.

The locomotive is the result of an accumulation of a multitude of facts; in its development, as one new truth or fact after another became mentally established, practice reflected the added knowledge. It has hence been through a process of integration, with hardly an important change in theory since the time of Stephenson. The details, by the immense advance of the processes of manufacture, by the improvement of machine tools, have been minutely examined and improved until we have, seemingly, as perfect a practical exhibition of theory as we can hope to attain. The tendency of first inventions is complexity. Inventors seem to be often far more ingenious in making a machine that will do a diversity of operations, many of which may be superfluous to the object at hand, than in producing simplicity.

One of the first requisites of the production of power is economy. Every superfluous part added increases the cost, first, by the material wasted, the expense of machines made to produce it, the labor of fitting and skilled workmanship; and second, by the expense of looking after and repairing it, and the constant and greater part, if it is a moving piece, by the force consumed by friction in running.

Hence, in such a machine as we are considering, it might be supposed that as improvements were made simplification would follow, until the limit is reached when only the essential parts of the mechanism to fulfil the definite and specific object for which the machine is to be employed, remain. This does not seem to be the case, thus far, however, in the example before us, for from the outset we see that we have not to do with a perfect instrument. To quote from Professor Thurston, "the process of improvement has been primarily one of differentiation, the number of parts has been continually increased, while the work of each part has been simplified, a separate organ being appropriated to each process in the cycle of operations." The parts have increased, some in the moving mechanism, some for safety and signals, such as the Westinghouse air or the vacuum brake, the bell, whistle, etc., and others for convenience in manipulation.

In all improvement in design of the locomotive engine, then, existing examples have been taken as the basis and the proportions of a new one founded, with certain modifications according to the kind of service for which it is to be made, entirely upon estimates from the experience of the designer.

In our study of the locomotive engine, the subject falls apart into what are called theoretical and practical aspects. "Practice provides the facts; theory the inferences in regard to those facts."

There are hence two directions in which inquiries lie, in order to produce as perfect a machine as our present stage of development will allow;—first, the treatment of the scientific principles which are applied in the locomotive, which would be a subject for theoretical treatment; and second, the manner of constructing the machine in accordance with these principles. The latter is practice. I will take the former as the leading method of inquiry and determine what the practice is, as far as may be, especially in regard to the efficiency of the apparatus,—to trace what becomes of the power as it is transmitted from one piece of mechanism to another.

Assuming the foregoing statements as the text of my remarks, I have thought that the best mode of treating the subject was to select a good pattern of locomotive, which, having its parts and proportions already given, the reasons for these proportions could be studied and their conformity to theory, in so far as that has been applied to the locomotive, ascertained. For this purpose I have taken a first class bituminous coal-burning passenger engine for a rather heavy passenger service, and built at the Hinkley Locomotive Works, in Boston. This engine is of the four driving-wheel and leading truck pattern, was designed and built in the latter part of 1875 for the Eastern Railroad Company, and is now running on one of the fast Pullman trains of that road. It was selected both on this account and for convenience, and as being a fair type of the coal-burning engines running on the New England Roads.

To illustrate the parts of this engine, five drawings have been made, which show the details as follows:—

Plate A. Side elevation, plan and rear elevation of a Hinkley passenger locomotive. Scale, $\frac{1}{2}$ inch to 1 foot.

Plate B. Details of locomotive;—cylinder, plan, longitudinal and cross section; piston, steam-chest, bed-plate, pump, cross-head, throttle, check-valve, etc. Scale, $1\frac{1}{2}$ inches to 1 foot.

Plate C. Details;—Main connecting rod, slides, yoke, eccentric rods, equalizing beam, crank pins, boiler brace, levers, etc.

Plate D. Details;—Frame, quadrant and reversing apparatus, link, rocker and driving spring.

Plate E. Tender for the Hinkley Locomotive,—side elevation, plan and rear view.

These drawings were traced from a set made at the Hinkley Works and published in Weissenborn's "*American Locomotive Engineering*," and show nearly all the important parts.* The details and arrangement of parts are correct and will be often referred to, although the design is for a heavier engine than that we are considering, and hence some of the dimensions given are too large.

The following is a complete specification of this engine, obtained, with care taken in regard to its correctness, both from the specification in the books at the Hinkley Works, and from actual measurements of the parts.

Boston, Oct. 25, 1875.

General Description.—One eight-wheeled heavy engine and eight-wheeled tender for the Eastern Railroad Company. Name, none. Road number, 55. Shop number, 1225. Gauge of road, 4 feet 8½ inches. Date of delivery, October 28th, 1875. To be a first class coal-burning passenger engine, having four driving-wheels coupled, a four-wheeled centre-bearing truck and eight-wheeled tender. All working parts thoroughly interchangeable, and all material warranted of the best quality.

DETAILS.

Engine.—*Cylinders*, of fine hard iron, placed horizontally, and bolted to frame and smoke-arch. Finish: lagged with wood and covered with brass; head of cast brass; steam chest trimmings of brass.

Diameter of Cylinders, 16 inches.

Length of Stroke, 24 inches.

Cylinder Cocks, worked with straight rod and lever in cab.

Oil Cups, cylinder oil cups on steam chests and gauge stand in cab with seamless brass tubes under lagging to steam chests.

Steam Ports: length, 14 inches; width, 1¼ inches.

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* The plates have been reduced to *one-half* their dimensions as drawn, and will be inserted, by permission, where referred to in the paper.

Exhaust Port: width, $2\frac{3}{8}$ inches.

Admission Ports: length, 14 inches; width, $1\frac{1}{4}$ inches. Offset face, $3\frac{1}{2}$ inches.

Exhaust Nozzle and tips, double; diameter, $3\frac{1}{4}$ inches.

Valves: Outside lap, $\frac{1}{8}$ inch; inside lap, $\frac{1}{32}$ inch; travel of valve, 5 inches.

Valve Motion: Links of hammered scrap iron, thoroughly case-hardened and made to cut off equally at all points of the stroke. Rockers and reverse shafts forged solid. Valve stems bushed with socket and key.

Rockers, of wrought iron; diameter of rocker shaft, $3\frac{1}{2}$ inches; arms, $9\frac{1}{2}$ inches long.

Links: 60 inches radius, 12 inches between centres; $13\frac{1}{4}$ inch lifters; pin, $\frac{3}{8}$ inch back.

Eccentrics, $13\frac{3}{16}$ inches diameter, 3 inches thick, 5 inch throw.

Piston Packing: Dunbar, two composition rings, babbitted. Iron cut into six pieces.

Piston Rods: diameter, $2\frac{3}{8}$ inches; length between shoulders, $34\frac{1}{8}$ inches.

Cross Heads of charcoal iron cast in dry sand, solid.

Slides: of steel; $45\frac{1}{4}$ inches long, 3 inches wide, $1\frac{1}{2}$ inches thick.

Yoke, of hammered iron, reaching from frame to frame.

Main Connecting Rods, length from centre to centre, 7 feet $4\frac{3}{8}$ inches.

Parallel Rods, length from centre to centre, 7 feet 6 inches.

Crank Pins: of steel; bearings, $3\frac{3}{16} \times 4$ inches, and $2\frac{3}{16} \times 2\frac{3}{4}$ inches.

Driving Wheels: Centres of cast iron, with hollow spokes, and rim. Diameter of centres, 57 inches.

Diameter of Driving Wheels, outside of tires, $62\frac{1}{2}$ inches.

Tires, of best Firthe's steel, imported, all flanged. Inside diameter of tire, 57 inches; width, $5\frac{1}{4}$ inches; thickness, $2\frac{1}{4}$ inches.

Driving Axles, of hammered iron; diameter of bearings, 7 inches.

Driving Boxes, regular. Length of journals, 7 inches; diameter, 7 inches.

Driving Springs, Nichols, Pickering and Co., Pittsburgh, 11 leaves.

Truck Wheels, N. Washburn's patent, with cast steel rims. Diameter of wheels, 28 inches.

Truck Journals: Length, 7 inches; diameter, $4\frac{1}{2}$ inches.

Truck Springs, N., P. and Co., 16 leaves.

Truck Frame, centre bearing. Frame of wrought iron, forged solid. Jaws of cast iron. Frame of 1¼ inch iron, 48⅞ inches wide.

Frame, of hammered scrap iron, forged solid, with lugs to hold cylinders. End rails wrought iron; front rail, 3½ inches deep, 3 inches wide; back rail 3½ inches deep, 3 inches wide; offset 9 inches, 18 inch jaw.

BOILER.—Wagon top, 7 inch offset, of extra flange charcoal iron, thoroughly stayed and riveted throughout and having one dome over the fire-box. Throat sheets and all horizontal seams double riveted; fire-box thoroughly stayed to shell and dome; shell of boiler flanged up into dome; smoke-arch raised up even with lagging by one inch bar. Height of back end, 88 inches; height of door, 40½ inches. Finish: boiler lagged with wood and covered with Russia iron, secured by finished brass bands.

Shell: Inside diameter 48 inches.

Thickness of Iron in Shell, ⅜ inch.

Thickness of Iron in Front Tube Sheet, ½ inch.

Tubes: of iron, 161 in number; length, 11 feet 0 inches; outside diameter, 2 inches; ⅝ inch water spaces.

Fire-Box, of homogeneous cast steel, Bay State plate, 60 inches long, 66 inches high, and 35⅝ inches wide inside.

Thickness of steel in ***Sides*** and ***Back*** of ***Fire-Box***, $\frac{5}{16}$ inch.

Thickness of steel in ***Tube Sheet***, $\frac{7}{16}$ inch.

Thickness of steel in ***Crown Sheet***, $\frac{5}{16}$ inch.

Grate, coal-burning. Length, 60 inches; width, 35⅝ inches; area of grate, 14·84 square feet.

Fire-Box Bracing: Centres of stay bolts not over 4 inches apart; centres of crown bars not over 4½ inches apart.

Dome. One on furnace, of cast iron, lagged with wood, and covered with brass; diameter 28 inches.

Smoke Stack: for coal burning, of cast iron, 13 feet 8 inches high from rail; length 61½ inches, with netting 38 inches in diameter.

Throttle Valve, 5 inches poppet.

Steam Pipes. Dry pipe, 5⅝ inches inside diameter; branches of cast iron 4½ inches in diameter.

Safety Valves, two in number, Richardson's patent, 2¼ inches in diameter, without levers.

Pumps. One right plunger pump, brass, with brass vacuum chamber. Valves of hard composition. Diameter of plunger 1⅞ inches.

Injectors. One No. 6 Mack's; on left side, overrunning board and taking water back of cock.

Check Valves, of brass, covered with brass.

Whistle, 6 inches in diameter; worked by shaft and lever in cab.

Bell, large pattern; posts of iron.

Sand Box, with cast brass rings, covered with brass.

Cab, of black walnut; 63⅞ inches long; well joint-bolted; roof covered with tin.

Pilot, of wood, vertical slats, well braced and ironed; iron broom stands.

Total Wheel Base, 21 feet 4½ inches.

Rigid Wheel Base, 7 feet 6 inches.

Wheel Base of Truck, 5 feet 6 inches.

Weight of Engine, with water, about 63,000 pounds.

TENDER.—*Tank* of best tank iron, well braced. Thickness of iron in bottom and inside of legs, ¼ inch; in top and sides, $\frac{3}{16}$ inch; frame of wood; draw casting, Miller's new pattern.

Wheels, eight in number, Washburn Iron Co., of chilled iron, 30 inches in diameter; axles, E. R. R.

Springs, cast steel, elliptic; front tender, N., P. and Co.; rocker, 17 leaves; back tender, ditto.

Capacity of Tank, 2,500 gallons.

Weight of Tender, empty, 20,000 pounds.

Air Brake Pump, on left side, between wheels.

Painting: All unfinished work of engine and tender to be neatly painted and varnished; boiler to have a coat of mineral paint under lagging.

Sundries: Each engine to be furnished with steam gauge; gauge, heater, blow-off, and water cocks; also oil cans, two jack-screws, two pinch-bars, wrenches, hammers, file, boxes, etc.

The details and action of the locomotive, as far as I shall be able to enter upon their discussion, in accordance with the preceding classification, may be regarded in the following order:

A, *The Boiler.* I, *The Shell;* its construction, material, strength, and factor of safety. II, *The Heating Apparatus* and *Boiler Proportion.* III, *The Feed Apparatus.* IV, *The Safety Apparatus.* And V, *The Transmission Apparatus*, or the *Distribution of the Power* to the engine. B, *The Engine.* I, *The Cylinder* and its proportion. II, *The Valve Gear.* III, *The Action of Steam in the*

Cylinder and the *Theory of the Blast.* IV, *The Transmission of Power to the Wheels* by means of the piston, crank and connecting rods. V, *The Running Gear.* VI, *The Balancing of the Engine.* And VII, *Tractive Power and Train Resistances.*

There are, then, three principal steps in the inquiry; first, that of the transfer of the energy of heat to the steam, in which we consider the heating surface, rate of combustion, evaporative power and efficiency of the boiler; second, the subject of boiler pressure, since that is the form which the energy next takes, and which should be traced through all its losses till it gives its energy up to the piston; and third, that of the actual power rendered available at the circumference of the wheels, or the tractive power, the adhesion of the wheels to the rails, the resistances of the train, and the equivalent horse power developed.

I. The Boiler of a Locomotive Engine is usually defined to be "a close vessel in which steam is generated."* It has two principal functions. It must first retain the energy obtained in the form of pressure; and, second, produce it most economically. The first relates to boiler strength; the second to its efficiency. The first, it will be proved, is at a maximum when the form given to the material of which the boiler is composed is spherical. The latter, it will be seen, depends upon obtaining the maximum amount of heating surface. These two requirements are opposed to each other, one being at a minimum when the other is at its maximum. The resulting form of boilers for the generation of steam, modified in accordance with each of these two principles, has been the cylindrical.

The locomotive boiler has these distinct parts,—the cylindrical shell called the barrel, or boiler proper; the internal and external fire-box attached to it; and the smoke box, upon which rests the chimney or smoke stack.

It is made up of several sheets of wrought iron, and in the internal fire-box, steel; of irregular shapes; bent to their proper form and riveted together by the system of single riveting, except in the longitudinal seams, which are double riveted. The names of these sheets or plates, referring to the position in the boiler which each occupies, are: the shell plates, off-set plates, side plates, bottom plate, front round head, front tube plate, back head, front furnace plate, crown sheet, dome plate, side plates, tube plate, ash pan, bottom and side plates, doors, and two smoke arch plates.

* Wilson.

The boiler proper is a cylinder 11 feet long and 48 inches in inside diameter, and made up of three cylindrical sections. Each of these sections is formed from a single plate, 56 inches in breadth and 156½ inches long, which wraps entirely around the circumference of the boiler. The ends of each of these plates are riveted together with a double row of diagonally placed rivets, and constitute a longitudinal seam in the boiler. The ends of the three sections which constitute the boiler shell, overlap one upon another, and are united by a single row of rivets around the circumference. In putting the sections together they shut one within another, not like the tubes of a telescope, but alternately over and under the edge of the section adjacent, so that the diameter of alternate sections is greater, by twice the thickness of the plate, than that of intervening ones.

Connecting the barrel of the boiler to the rectangular fire-box with its arched top are diagonal plates, shown in Plate A, at *a*, Fig. 1, four in number, called the off-set plates, which increase the radius of the outer shell at the fire-box end by 7 inches. The under plates are bent so as to form flanges upon which to rivet the vertical front side of the external fire-box.

The barrel of the boiler consists of the outer shell, which has at its extremities the two tube plates, placed 11 feet apart, and connected by 161 tubes, each 2 inches in diameter; the smoke-box, and the bracing. The smoke-box is simply an extension of the shell by an additional section, which forms a receptacle for the hot gases as they come in detached currents through the tubes from the fire box. The bracing consists of diagonal stays for the ends, angle iron, and ten longitudinal stay rods passing from the front tube sheet, through the steam space above the tubes to the back end of the boiler, and fastened by nuts and washers upon the outside. The boiler has lagging, which consists of felting and wood, covered with Russia iron, and held down by bands of brass running around the boiler.

The qualities which it is most desirable to obtain in the construction of the steam generators of locomotives, are: *adaptation* to the circumstances of their use;* *durability* or economy in the cost of repairs; *economy in construction*, in material and workmanship, by which weight would be reduced till limited by the other conditions; *strength*, to sustain both the internal pressure and other forces

* Trowbridge.

coming upon it; and, finally, *efficiency* or economy in evaporative qualities—to decrease the expense of maintenance, to produce more power without increase of weight, and to employ as thin heating surface and as great in extent as possible, without influencing in an injurious way the other conditions.

How nearly the locomotive boiler fulfils these conditions would form too large a subject for discussion here, and I will hence take up, in a general way, only the problems of boiler strength and efficiency.

The materials in use for locomotive boilers are wrought iron for the shell, and copper or steel for the fire-box. The advantages of copper are soundness, easy working, little corrosion or oxidation, ductility in working and flanging, and its superior conducting power to iron. Its disadvantages are its cost, softness, in resisting the abrading action of the particles of coal as they are driven against such parts as the crown sheet or tube plate, its loss of strength on being heated, and the greater thickness required for strength, which overbalances its superior conducting power. The unequal expansion, also, of two metals of so dissimilar a constitution as copper and iron, when used together, has an important influence.

Wrought iron has many advantages and but few defects, the greatest of which is its rusting. It is perfectly reliable, which cannot as yet be said of steel, for the unaccountable way in which that, apparently of the best quality, cracks in the fire-boxes when the boiler is cooling down, separating sometimes through the rivet holes, but often diagonally or between them, has formed a subject for almost endless discussion.

Experiments on Tensile Strength of Boiler Plate, made by C. B. Richards, Esq., M. E., Hartford, Conn.

Kind of Iron and its Brand.	Ultimate Tenacity—Tensile Strength per Square Inch, Original Cross Section.		
	Strongest Specimen. Lbs.	Weakest Specim'n Lbs.	Averages. Lbs.
Bay State Flange iron.....	52993	50770	52102
Bay State homogeneous metal (steel).....	71139	70100	70672

Wrought iron increases in strength on heating, up to 570°,* and its properties, as well as those of steel, in respect to tensile strength,

* Experiments by Franklin Institute.

are best shown by the table inserted, which gives the facts concerning the metals that are used in the locomotive under consideration.

The iron and steel for this locomotive were furnished to the Hinkley Works on the authority of these experiments, and were not tested by them before being made up into the boiler. We may then safely take the ultimate tenacity of these two metals at the figures given in the column of averages.

(To be continued.)

THE MANCHESTER STEAM USERS' ASSOCIATION.

From *Scientific American Supplement*, New York, October 21, 1876.

At the request of the Judges, Group 20, of the American Exhibition, the Manchester Association sends the following particulars of the operation of their society :—

Offices : 9 MOUNT STREET, MANCHESTER, July 4, 1876.

THE CENTENNIAL COMMISSION, INTERNATIONAL EXHIBITION, PHILADELPHIA.

For the Use of the Judges in Group 20.

Gentlemen :—In reply to a letter received from Mr. Chas. T. Porter, requesting information as to the working of the Manchester Steam Users' Association, for the use of the Judges of the International Exhibition, Philadelphia, I beg to forward the following particulars, and in doing so will take up the points seriatim, in the order in which they occur in Mr. Porter's letter.

No. 1. "*Term of Existence.*"—The Association was established in the year 1854, and has been in active work ever since, increasing in the number of its boilers and the area of its operations.

No. 2. "*Average and Present Number of Boilers in charge.*"—The number of boilers now under inspection is as nearly as may be 3000. The average for the last five years has been 2500.

No. 3. *Character of the Boilers, and if of different types the number of each.*—By far the greater number of boilers enrolled with the Association are horizontal, and internally fired. Speaking approximately, the relative number of the various types is as follows :—

50 per cent. are what are termed "Lancashire" boilers; that is to say, having two internal tubes running through them from end to end, in which the fires are placed.

15 per cent. are of the "Cornish" Type; that is to say, having one furnace tube running through it from end to end, in which the fire is placed.

15 per cent. are externally fired, such as plain cylindrical, egg-ended colliery boilers; French or "Elephant," and "Butterly" boilers.

8 per cent. are variations of the "Lancashire" and "Cornish" boiler, with a number of small flue tubes, some termed multiflued, and others multitubular, etc.

6 per cent. are of the "Galloway" type.

6 per cent. are of miscellaneous types, such as boilers at iron-works heated by flames passing off from puddling and iron furnaces, water-pipe boilers, locomotive and marine boilers, and vertically internally fired boilers, etc. This proportion varies somewhat year by year, as boilers are changed.

No. 4. *Pressure carried—between what limits.*—All the "Lancashire" boilers made for members under the inspection of the Association, the ruling diameter of which is 7 feet in the shell, and 2 feet 9 inches in the furnace tubes, are fit for a working pressure, as a minimum, of 75 pounds on the square inch. Many are fit for a pressure of 85 pounds, others 90 pounds and 100 pounds. No new boilers are made to the Association's standard for a lower pressure than 75 pounds on the square inch. Many smaller boilers are carrying 120 pounds.

No. 5. *Character of the Examinations made, and their frequency.*—A complete examination of every boiler is made both inside and outside, when at rest and properly prepared, at least once a year, and more often if necessary: that is to say, if the boiler does not appear thoroughly sound or repairs have to be examined. Hydraulic tests are also had recourse to when necessary. In addition to the annual thorough examination, two "external" examinations are made of each boiler per annum, with the boilers at work and steam up. This number is a minimum.

No. 6. *Nature of the Defects and the Number of each per annum.*—The following is a list of the defects discovered, with the number of each for the year 1875:

Furnaces out of shape	22;	3 dangerous.
Fractures	87;	10 "
Blistered plates	79;	6 "
Internal corrosion	163;	5 "
External corrosion	104;	21 "
Internal grooving	117;	1 "
External grooving	9;	2 "
Feed apparatus out of order	1	
Water-gauges "	7	
Blow-out apparatus "	14;	3 "
Fusible plugs "	6	
Safety valves "	30;	8 "
Pressure gauges "	110;	7 "
Boilers without glass water-gauges	2	
" " safety valves	8;	1 "
" " pressure gauges	6;	4 "
" " blow-out apparatus	6	
" " feed back-pressure valves	51	
Cases of over pressure	9;	5 "
Cases of deficiency of water	2;	1 "

Total—defects, 833; 77 dangerous.

No. 7. "*Instructions given to Owners and Firemen.*"—We have no written code, but are thinking of preparing a list of instructions to firemen. All we ask from the owners is, to get a good boiler and a careful man. We impose no arbitrary conditions. Information to the owners is always accessible at these offices.

No. 8. *The Guarantee afforded to Members.*—The Association guarantees the members freedom from explosion, and the Association's guarantee has never failed. Its members continue to enjoy immunity from explosion year after year. As a pledge of good faith, the reports are endorsed with a pecuniary guarantee of £300, but the Association has no explosions. The only exception to this was the rending of a furnace through overheating in consequence of misuse by the owner, who charged the boiler heavily with caustic soda and arsenic, bringing down the incrustation but yet neglecting to blow out. No one was hurt, and the boiler was soon repaired and set to work again. We warn our members against using compositions and neglecting to blow out. We guarantee our members perfect immunity from explosion, provided only they meet us with ordinary fairness. Year after year we are able to report "*No explosion from any boiler guaranteed by the Association.*"

No. 9. *The Cost to Members of the Inspection and Guarantee.*—The charge for inspection is one guinea and a half per annum each boiler, within a radius of 40 miles of Manchester; beyond that distance according to arrangement. There is no charge for guarantee. The Association's guarantee is neither to be bought nor sold. If the Association considers a boiler unsafe, nothing will induce it to say it is safe. If the boiler is safe, there is no need to charge for saying so. The expenditure is incurred in inspection, and the Association has no explosions to make compensation for.

No. 10. "*The Result of the Work of the Association in Immunity from Accidents.*"—It is presumed that by the word "accidents" is meant explosions. Explosions in the great majority of cases are *not* accidental. They arise from known causes. Inspection is able to prevent their occurrence, and is found in the experience of the Association to be quite adequate. *See here reply to question No.* 8.

No. 11. *Upon what do you rely for Safety?*—Upon competent periodical inspection. *See reply to questions* 8 *and* 10.

No. 12. "*Low-water Detectors.*"—We recommend that each boiler should have two good glass water-gauges, fixed directly to the front end plate of the boiler, immediately under the eye of the attendant. We approve of a low-water safety valve which relieves the pressure of the steam as soon as the water falls below the desired level. Alarm whistles may be easily silenced, and, as a rule, have been discarded. A low-water safety valve is more reliable, as it blows off either for high steam or low water, and thus is kept in constant play.

No. 13. "*Automatic Feed Regulators.*"—We do not approve of these, thinking them apt to mislead, and to engender a false confidence. We prefer feeding by hand as more trustworthy.

No. 14. "*Testing Boilers in use by Hydrostatic Pressure.*"—We do not adopt this course as a rule, and only adopt it where there is some peculiarity in form, say to ascertain the strength of a flat surface, or when any question arises as to the power of a furnace to resist collapse. In the case of the cylindrical shells of boilers, we rely on careful inspection. If the plates appear to be wasted we drill them to ascertain the precise thickness, and sound the rivet heads to see if corrosion is interfering with the consistency of the metal. We have the boiler so set that all parts may be accessible to examination. If the brickwork interferes we have it removed. When hydraulic tests are applied, the boilers are gauged at the flat ends, and also in the furnace

tubes, to see if any movement occurs. We have no faith in "blind" hydraulic tests for getting at the strength of parts out of sight. Our rule is to see everything.

No. 15. "*The Experience and approved Usages of other Similar Associations in England.*"—The object of the Manchester Steam Users' Association is the saving of human life, and the prevention of explosions. It has no shareholders and pays no dividends. The President and members of the Executive committee give their time gratuitously year after year in the interest of the members and the public generally, with the object, as already stated, of saving life. There is no other similar association in the country, but there are joint-stock boiler insurance companies, founded for the purpose of dividend. I think I have now replied to all the inquiries contained in Mr. Porter's letter, but may add that our Association goes to the expense of sending a qualified officer to investigate every explosion that occurs in any part of the country, and draw up a full report, with illustrative drawings of the same. These are carefully preserved at the offices, and form most instructive and valuable documents. A very abridged statement of the description of boiler, course of the rents, effects of the explosion, and the cause, is given in a tabular synopsis published in the Association's printed monthly reports, circulated amongst the members, and sent to the press gratuitously, so as to disseminate the information as widely as possible.

The Association has boilers enrolled under its inspection situated in all parts of the United Kingdom. Also it has several corresponding members abroad, and is affiliated with another institution for the periodical inspection of boilers at Calcutta. Its monthly reports will be found in the library of the Franklin Institute at Philadelphia.

Trusting that this information will be of service to you, and wishing you every success in your labors,

I remain, Gentlemen, yours faithfully,

L. E. FLETCHER, *Chief Engineer.*

St. Gothard Tunnel.—An international commission charged with the duty of reporting upon the St. Gothard Tunnel have officially remarked that, thanks to the improved machinery which has been introduced, the works have made great progress of late, so that, unless unforeseen obstacles should supervene, it will in future be comparatively easy to complete the tunnel at the average rate of 20 feet per day.—*Engineering.*

ON ROPE GEARING FOR THE TRANSMISSION OF LARGE POWER IN MILLS AND FACTORIES.*

By Mr. James Durie.

[A Paper read at the Meeting of the Institution of Mechanical Engineers, at Manchester, England, October 25, 1876.]

The best means of transmitting power from the prime mover to the various machines in a factory has long been a matter of importance to the engineer and to the manufacturer. Until lately, toothed gearing—either as spur or bevel wheels, or a combination of both—has been almost universally employed for first motions, the smaller powers being taken off pulleys by leather belts. The facility of taking small powers off drums to machines by means of belts, and the absence of noise and vibration, led to the adoption, in the United States of America, of broad leather belts for the transmission of large powers from the prime mover to the shafting in factories; and the success which has followed the adoption of these large belts there, has led to their being adopted by many users of power in this country.

The object of the present paper is to bring before the institution the plan of transmitting large powers by means of round ropes working on grooved wheels, which, in some parts of this country, has been largely adopted as a substitute for toothed gearing. The experience gained by the firm with which the writer is connected, in this mode of transmitting power, has extended over a period of thirteen years; and wherever it has been employed, either to replace toothed gearing in old or for new works, it has always given complete satisfaction.

In this mode of driving, the fly-wheel of the engine is made considerably broader than the fly-wheel of an engine having cogs on its circumference; and, instead of cogs, a number of parallel grooves for the ropes are turned out, the number and size of which are regulated by the power to be taken off the fly-wheel. The power which each of the ropes will transmit depends upon their size, and the velocity of the periphery of the fly-wheel. The ropes employed are of two sizes for large powers, namely, 5¼ inches and 6¼ inches circumference; another size of rope, 4¼ inches circumference, is employed for small

* From *Iron*, London, Oct. 28, 1876.

powers, but there is no definitely ascertained limit to the size of ropes that may be employed. Where large powers are required, and where large pulleys can be used, it is best to use heavy ropes, and the contrary when the opposite is the case.

The velocity of the periphery of the grooved fly-wheel and pulleys is generally arranged to be between 3,000 and 6,000 feet per minute; and the velocity being settled and the power of the steam engine known, the number of the ropes required to transmit the power is then determined, from the experience that has been gained of the amount of power transmitted by ropes in previous cases. It is very essential that the right proportion between the diameter of the ropes and the pulleys is obtained; if the diameter of the pulley is too small, the rope in continually bending over them is apt to strain the strands and grind the core into dust, and on the size of the pulley in a great measure depends the life of the rope. As a general rule the circumference of a pulley should not be less than thirty times that of the rope which works on it. In apportioning the distance between the driver and the driven shafts, great latitude may be taken —a distance of from 20 to 60 feet may be taken as a fair space.

The mode of applying a complete system of rope gearing may be seen at a factory for spinning and weaving jute belonging to Messrs. A. and J. Nicoll, at Dundee, and fitted up by Messrs. Pearce Bros., Lilybank Foundry, of that town; this gearing has been working from June, 1870. The engine fly-wheel is 22 feet diameter, and has eighteen groves cut in its circumference; its width is 4 feet 10 in. over all. The engine makes 43 revolutions per minute, and the velocity of the periphery of the fly-wheel is 2,967 feet per minute. The power of the engine varies from 400 to 425 ind. h. p.; the power transmitted by each of the ropes, which are 6½ inches circumference, is, therefore, about 23 h. p. The power is transmitted to the ground floor by five ropes on to a pulley 7 feet 6 inches diameter, the power required being 115 ind. h. p.; that to the first floor by four ropes to a pulley 5 feet 6 inches diameter, the power required being 92 ind. h. p.; and that to the attic by six ropes on to a pulley 5 feet 6 inches diameter, the power required being 138 ind. h. p.; two shafts being required in this room, the power to the second shaft is transmitted by horizontal ropes, whilst on the other side of the engine shaft three ropes transmit 69 ind. h. p. to a weaving shed, the pulley being 7 feet 6 inches diameter. The ropes should never

be so heavily loaded as to draw them, even on short spans, to a near approach to a straight line; in this factory each rope, traveling at a velocity of 2,967 feet per minute, transmits, as above, 23 ind. h. p., the tension on the rope is, therefore, $\frac{33{,}000 \times 23}{2{,}967} = 256$ lbs., which is a very long way under the breaking strength of the ropes.

The ropes do not rest on the bottom of the groove, but on its V-shaped sides; these sides are generally made at an angle of about 43° to each other. If the angle at which the grooves are formed is very obtuse, the ropes will slip; if too acute, much friction may be caused by the rope becoming wedged into the groove. As the sum of the tensions upon the two parts of a band is the same, whatever be the pressure under which the band is drawn or the resistance overcome, the returning side of the rope is as much slackened as the working side is tightened. It is therefore generally advisable, when it can be so arranged, to have the tight or driving side of the ropes at the bottom, so that the returning side may lap round the top of the pulleys, and consequently obtain extra bearing surface; when the opposite is the case, the ropes fall sooner out of the grooves, and so lessen the bearing surface. It is not always practicable to arrange this, and in the case of taking the power off both sides of the driving pulley, it is obviously impossible.

None of the shafts of this factory are driven from the fly-wheel by less than three ropes, the strain on each rope being only, as shown above, 256 lbs.; it may therefore be supposed that a greater weight may temporarily be put upon a rope, in case any of the ropes should require to be tightened up, and this is often done. A rope is taken off at a meal hour, respliced, and put on again at the next stoppage of the engine, thus avoiding any necessity for night work or overtime. Night work should always be avoided, for besides the extra expense incurred, the work is never so well done by artificial light as it is done by daylight.

In the Samnuggur Jute Factory, Calcutta, which is a one-story building, all the machinery, both spinning and weaving, is on the ground floor. The engines are placed near the middle of the building; they are about 1,000 ind. h. p., and make forty-three revolutions per minute; the fly-wheel is 28 feet diameter, and its width 6 feet 7 inches; the velocity of the periphery being 3,784 feet per minute. The ropes are 6¼ inches circumference, eighteen ropes transmit the

power to the right hand or spinning side, and seven ropes to the left hand or weaving side, making a total of twenty-five ropes; each rope therefore transmits 40 ind. h. p. The tension on each rope due to this load at the above velocity is $\frac{33{,}000 \times 40}{3{,}784} = 349$ lbs., which is rather a heavier load than in the previously described factory; all the shafts are also driven by more than one rope, with the exception of some of the line shafts in the weaving shed. Rope gearing was only adopted in this case after the most searching inquiry as to its suitability for working in the warm and humid climate of Calcutta, and its adoption has been attended with very satisfactory results, both in this case and also at the Sealdah Mills in Calcutta.

The drawings show the arrangements adopted when the factories have been specially designed for rope gearing, but this gearing has often been applied to replace toothed gearing in mills already built. The plan then adopted is to put in a new grooved fly wheel, or to place grooved segments upon the existing fly wheel, when the speed is sufficiently great to allow of a limited number of ropes being employed, and the width of the wheel pit is also sufficient for the purpose; but if this plan cannot be adopted, grooved pulleys are put on the second-motion shaft, and the ropes carried to the different stories of the mill. It has even sometimes been necessary to put in a counter shaft, so as to gain speed and get sufficient length between the centres of the shafts on which the pulleys are placed.

A comparison has now to be made between the system of rope gearing and the other two systems in use at the present time. The system in most general use is toothed gearing; in this the first driver is the spur wheel fitted on to the crank shaft of the engine, into which is geared the driven pinion of smaller size. In order to insure these two wheels working well it is absolutely essential that the centres of the engine shaft and the shaft of the pinion are rigidly fixed at the correct distance from each other, and that the teeth of the two wheels are accurately of the same pitch and size. The first of these objects is obtained by making the engine bed, in a horizontal engine, a strong rigid casting resting on an expensive ashlar foundation, or in a beam engine the foundations are alone depended upon. If these objects are obtained, the wheels ought to work smoothly and without much noise; but how often this desirable object is obtained, it only requires a walk to be taken through the streets of a

manufacturing town, to ascertain by the rumbling noise, sometimes heard at a distance of several hundred yards, that all is not as it should be for the safe and economical transmission of the power of the steam engine. If the factory consists of more than one story, the power has to be taken from the second-motion shaft, by means of an upright shaft and bevel wheels, requiring heavy wall boxes, and strong walls to keep the wall boxes in their places; the whole object in the construction of the factory being to secure a rigid and immovable structure, a matter which is very difficult to attain.

In the case of rope-gearing, the ropes by which the power is transmitted consist of an elastic substance, and their lightness, elasticity, and comparative slackness between the pulleys, are highly conducive to their taking up any irregularity that may occur in the motive power. This accounts for the slight attachments that are required for shafting driven by ropes from a grooved fly wheel; and it is the same with all the bearings throughout the mill, the shafts in the various flats only requiring a light wall box, bracket, or the bearing may be carried on a column of the mill. The cost of fitting up a mill with rope gearing is considerably less than with tooth gearing, when the shafts to be driven revolve at a high speed, but the cost is about the same in other cases. It is, however, rather difficult to give exact figures for this comparison, one great saving being in the foundations of the engine, the wall boxes, and the extra strength of the walls required for upright shafts.

The great advantage of rope gearing, however, is the entire freedom from any risk of a breakdown; when a rope shows symptoms of giving way—and ropes always give symptoms of weakness long before they break—the weak rope can be removed and another put in its place at any meal hour or evening. The cost of the maintenance of ropes for transmitting 400 ind. h. p. has been found to be £20 per annum, or about £5 per 100 ind. h. p. per annum. This is made up of the cost of renewal of the ropes, and occasional wages for tightening them. Some ropes have been found to run ten and a half years, but as the general rule, the life of a rope may be said to be from three to five years, though even five years has been often much exceeded.

The friction of rope gearing has often been found to be, for high speeds, considerably less than that of toothed gearing; but the writer regrets not being able to give definite information on this point, which is a very important one to those contemplating altering

their gearing or building new works. The reason why no definite reason can be given—beyond the universal impression of those who have adopted them, that ropes require less power to drive than toothed gearing—is, that in all cases where rope gearing has been substituted, other alterations have been made at the same time, or the engines were, after the alteration, driven at an extra speed of ten or fifteen revolutions per minute. However, every one who has substituted rope gearing for toothed gearing, also agrees in bearing testimony to the great improvement and steadiness of driving obtained after the alteration, and that they are enabled to turn off a greater amount of yarns from the machinery in the same time. The tendency at the present time, with the introduction of shorter hours of labor and foreign competition, being to increase the speed of shafting and machinery, to be able by this means to increase the speed of the shafts must be of great advantage to those who own old mills, the toothed gearing of which is generally driven as fast as it is safe to drive it.

The ropes used for rope gearing are mostly made of hemp, carefully selected; the qualification of a good rope being that the fibres are as long as possible, and that the rope should be well twisted and laid, and yet be soft and elastic. It is also very important that the ends of the ropes should be united by a uniform splice—the splice should not be of a greater diameter than the other part of the rope; to effect this object the splice is made about nine or ten feet long.

The comparison between rope gearing and toothed gearing having been made, it remains to compare ropes and leather belts, which latter have been largely used in the manufacturing districts of Lancashire and Yorkshire, for the transmission of large powers. The writer has not been able to obtain very satisfactory information as to the amount of power absorbed in friction by large belts; in some cases it has been said to be more, and in some less, than with toothed gearing. The most trustworthy information he has obtained is in the case of a four story woolen mill, where an upright shaft, with bevel gearing, was replaced by two belts, one 22 inches wide, and the other 27 inches wide, the power transmitted being 400 ind. h. p., and the speed of the belts 3,000 feet per minute. The driving pulleys are on the second-motion shaft. In this case the power is stated to be the same with the belts as it was before the alteration; but, as in the case of rope-driving, the "turning" is found to be much superior to what it was before the alteration. The width of the pulleys for

ropes is generally rather less than for belts transmitting the same power; but there is some difference of practice as to the width of belt used for transmitting a certain power. The cost of hemp ropes is considerably less than of leather belting, the cost of hemp ropes being about 1*s.* per pound against 3*s.* per pound for leather belts. The grooved pulleys for ropes cost more than plain pulleys, but making allowance for this, the total cost of ropes and grooved pulleys for transmitting a given power, does not exceed one-half or two-thirds the cost of leather belting and flat pulleys. The advantage of ropes over belting, however, lies in the power being divided up into a number of ropes, so that in the case of any one of the ropes showing symptoms of weakness, that rope may be removed by stopping the engine for a few minutes, the remaining ropes continuing to do the work until a stoppage of the engine occurs. In the case of belting, as only one belt is employed to drive one flat of a mill, if anything were to occur to the belt, the whole of that flat would be stopped until the belt was repaired.

Judging from the practice adopted, the comparative amount of power transmitted by certain sizes of ropes and widths of double belts, the writer finds that a 6½ inch circumference rope does about the same amount of work at a given speed of say 3,000 feet per minute as a belt 4 inches broad. This width, however, represents the smallest width adopted as a rule, 5 inches corresponding to the American practice, but taking a 4 inch belt, the bearing surface of a 6½ inch circumference rope on the sides of the grooves on a 4 feet 6 inch pulley will be half the circumference, or 85 inches, and allowing the rope half an inch width of bearing on each side, or 1 inch for both sides, the total bearing surface is $85 \times 1 = 85$ square inches, whilst the belt has $85 \times 4 = 340$ square inches, or four times the amount. Consequently, in order that a 6½ inch circumference rope may transmit as much power at the same tension as a 4 inch belt, the effective pressure per square inch of the bearing surface of the rope on the pulley must be at least four times as great as that of the belt.

In order to obtain some information bearing on this point, a set of experiments have been made by Mr. A. W. Pearce, at Lilybank Foundry, Dundee, the results of which are given in the following table. The experiments were made with the materials at hand; both the pulleys were just as they came from the lathe, and equally smooth, and they were nearly the same size as named in the table. Comparing together Nos. 2 and 5 experiments, it is seen

that a 6 inch circumference ungreased rope, with 336 lbs. suspended at one end, and passing over a 4 feet 9 inch grooved pulley which was at rest, required only 28 lbs. at the other end to prevent slipping; whilst a half-worn good single leather belt, 4 inches wide, with the same weight at one end, and passing over a 4 feet 6 inch pulley, required 113 lbs. at the other end to prevent slipping, or about four times as much as with the rope. The bearing surface of the rope would be only about one-fourth that of the belt, and the effective pressure per square inch of the bearing surface of the rope was consequently in this case sixteen times as great as that of the belt. In the experiment No. 4 a double leather belt, 6 inches wide and $\frac{3}{4}$ inch thick, with the same weight at one end, and passing over a 4 feet 6 inch pulley, required 98 lbs. at the other end to prevent slipping, or $3\frac{1}{2}$ times as much as with the 6 inch circumference rope. The experiments show, however, such a great difference between the results with different sizes of ropes as to make it impossible to come to any definite proportion between the friction of ropes and belts; but they show, as was to have been expected, that ropes have a considerably greater hold on the $\vee$-shaped grooves per square inch of bearing surface than flat belts have on pulleys.

EXPERIMENTS ON THE FRICTION OF ROPES AND LEATHER BELTS ON CAST IRON TURNED PULLEYS.

No. of Experiment.	Rope or Belt	Circumference of rope or width of belt.	Diameter of pulley.	Load suspended at one end.	Weight required at other end to prevent slipping.		Remarks.
					Ungreased.	Greased.	
		Inch.	Ft. In.	lbs.	lbs.	lbs.	
1	Rope.	7	4 9	336	56	102	Rope somewhat worn.
2	"	6	4 9	336	28	90	Rope new.
3	"	$5\frac{1}{4}$	4 9	336	14	..	Rope new.
4	Belt.	6	4 6	336	98	133	Double belt $\frac{3}{4}$ in. thick.
5	"	4	4 6	336	113	..	Single belt half worn.

NOTE.—The rope pulley used in these experiments was grooved for $6\frac{1}{4}$ inch circumference of rope.

The writer has been informed that in the United States several rolling mills are driven by means of flat leather belts, and that very satisfactory results are obtained by their use, and he wishes to draw the attention of members engaged in this department of manufacture to the suitability of rope gearing for this purpose. Although he is not aware of any practical example of its having been applied to driving rolling mills, he is confident that from the slackness with

which the ropes can work, and the hold they have on the grooves of the pulleys, they would be admirably adapted for taking up the shock which is thrown upon the gearing of a train of rolls when the iron enters the rolls.

Mr. Welsh opened the discussion by a mathematical criticism of the principles involved in the paper, arriving at a corroboration of the angle of 40°, approved by Mr. Durie, on the ground that the tangent of half this angle (0·364) ought to be equal to the coefficient of friction, which, taking the mean of the writer's experiments, was 0·399. He enforced his remarks by symbols and formulæ of fearful complexity, inscribed upon the blackboard.

Mr. Paget said that he had been working in the same direction, and had performed over 900 experiments with a view of getting at some general principle. The results, however, were so absurdly discordant that he had abandoned the task. His best results corroborated Mr. Durie's angle of 40°.

THE DURATION OF A BLOW.

[From *Engineering* London, Oc. 27, 1876.]

In a recent number of *Engineering* (*vide* page 330 *ante*), a paper was reprinted,* describing an ingenious method by which very small intervals of time occurring between two successive mechanical movements may be determined with a considerable degree of accuracy. For the determination of the velocities of projectiles this method, which has been devised by Mr. Robert Sabine, would probably not be so applicable as the ordinary chronoscope systems, unless the time interval to be determined were less than the $\frac{1}{1000}$ of a second, when it would become superior, from the fact that electricity having no appreciable inertia there is no limit to the smallness of the interval, which may be measured by means of its outflow from an accumulator. But for the determination of the duration of contact between metallic surfaces during a blow it is the only system which can afford us any information at all. For this reason the following series of experiments, with the details of which we have been favored by Mr. Sabine, will be regarded with much interest.

These experiments, which were intended as preliminary to a more extended inquiry, were made with a view to find approximately how the duration of a blow varied with the weight of the hammer, its

* *Philosophical Magazine*, May, 1876.

velocity of descent, and with the materials. An iron ball, weighing ¼ lb., was suspended by a fine wire from an insulated support upon the ceiling, so that when it hung vertically it just grazed the vertical face of an ordinary blacksmith's anvil placed upon its side on a table. By raising the ball and letting it swing against the face of the anvil a blow of varying force could be struck. On rebounding, the ball was arrested whilst the excursion of the galvanometer needle was observed. By measuring the angle through which the ball was separated, its vertical fall and final velocity could be easily deduced. In this way the greatest vertical height from which the iron ball was let fall on to the face of the iron anvil was 4 ft., the least about $\frac{1}{80}$ inch. Six readings were taken for each height, and they were invariably found to agree amongst each other. The means only are given in the following records:

Vertical Fall in Inches.	Duration of Contact in Seconds.
48	0·00008
36	0·00008
28	0·00008
17	0·00009
9¼	0·00010
4	0·00011
1	0·00013
0¼	0·00016
$0\frac{1}{16}$	0·00018
$0\frac{1}{32}$	0·00021
$0\frac{1}{80}$	0·00030

From this it would appear that when the velocity of a blow is increased, the duration is decreased within a certain limit: but that it reaches a minimum. The velocity of impact in the first experiment was about sixty times as great as in the last one; but the duration of the blow appears to be reduced only to about one-fourth of the time. The blows given by two hammers of different weights were compared. No. 1 weighed 4 oz., No. 2 weighed only 2¼ oz. The durations of the blows were as follows:

	Duration of Contact.	
Vertical Fall.	Ball No. 1.	Ball No. 2.
in.	seconds.	seconds.
1	0·000135	0·000098
4	0·000096	0·000083

It appears from this that a heavier hammer of the same material gives a longer duration of blow.

In the course of these experiments it was observed that the ball after striking the anvil rebounded irregularly, sometimes to a greater, at others to a less height, and that some relation appeared to exist between the heights to which the ball rebounded and the excursions of the galvanometer needle due to the residue of the charge.

In the next series, therefore, the rebounds of the iron ball from the iron anvil were measured and recorded, from which it appeared that when the rebound was greater the duration of contact was shorter, and *vice versa*.

Vertical Fall.	Vertical Rebound.	Duration of Blow.
in.	in.	seconds.
6	2	0·000120
6	$2\frac{1}{2}$	0·000111
6	$3\frac{1}{4}$	0·000101
6	$3\frac{1}{2}$	0·000091
$14\frac{1}{2}$	$3\frac{1}{4}$	0·000106
$14\frac{1}{2}$	$4\frac{1}{2}$	0·000103
$14\frac{1}{2}$	$5\frac{1}{4}$	0·000095
$14\frac{1}{2}$	$6\frac{1}{2}$	0·000086
25	$7\frac{1}{4}$	0·000096
25	$8\frac{1}{4}$	0·000091
25	$9\frac{1}{2}$	0·000086
25	12	0·000078

The explanation of this is probably that when the energy of the blow is expended in bruising or permanently altering the form of the hammer or anvil by which the contact of the two is prolonged, it has less energy left to enable it to rebound, and *vice versa*. Substituting a brass anvil and brass ball, it was found that the blow was duller, the rebound much less, and the duration of contact nearly three times as great as when an iron ball and anvil were used.

Vertical Fall.	Vertical Rebound.	Duration of Contact.
in.	in.	seconds.
$1\frac{3}{4}$	$0\frac{1}{8}$	0·00036
6	1	0·00033
$14\frac{1}{2}$	$1\frac{1}{2}$	0·00026
25	2	0·00027

This series shows also the longer duration of the blow when its velocity is small. Using a brass anvil and iron ball the duration of the blow was greater than when both were of iron, but less when both were of brass.

Vertical Fall.	Vertical Rebound.	Duration of Contact.
in.	in.	seconds.
$1\frac{3}{4}$	$0\frac{1}{8}$	0·00021
6	$0\frac{1}{2}$	0·00018
$14\frac{1}{2}$	$1\frac{1}{8}$	0·00015
25	2	0·00014

Striking the brass anvil with a common hammer, the duration of the blow appeared shorter when struck sharply.

	Duration of Contact. seconds.
Moderate blow, .	0·00027
Harder blow, . .	0·00019

Striking the blacksmith's anvil with a common carpenter's hammer, the duration appeared to be nearly constant:

	Duration of Contact. seconds.
Moderate blow, ...	0·00011
Harder blow, ...	0·00010

It was, of course, necessary to allow in each case the hammer to rebound freely, and not to prevent it doing so by continuing to exert any pressure at the instant of the blow. When this condition was observed, in was invariably found that the harder and sharper the blow the shorter was its duration. It was also noticed that whenever the anvil gave out a sharp ringing sound, the duration of the blow was much shorter than when the sound was dull.

A very slight error would be introduced by reason of thermo-currents set up between the metals at the moment of the blow. By reversing the direction of charge of the accumulator, however, the effect from this cause was found to be quite inappreciable. Mr. Sabine's experiments are, as we have said, altogether very interesting, and we hope hereafter to be able to record the results of his further researches.

Purification of Bisulphide of Carbon.—M. L. H. Friedburg.—The author distils the sulphide over a pure vegetable fat, such as palm oil. To free the sulphide of carbon from a little fatty matter which it carries over, it is poured into fuming nitric acid, stirred, and allowed to digest for twenty-four hours. It is then mixed with cold water, distilled at 50° or 60°, mixed with water again, and re-distilled, when it is obtained perfectly pure.—*Berichte der Deutschen Chemischen Gesellschaft zu Berlin.*

Errata.—For Article on the Strength of Thick Hollow Cylinders.

Correct page 330, line 21, for Dividing by dr, read Dividing by $r\,dr$.

Correct page 331, line 3 (from bottom), for

$$= \alpha - \beta\left(\frac{du}{dr} - \frac{u}{r}\right), \text{ read } (\alpha - \beta)\left(\frac{du}{dr} - \frac{u}{r}\right).$$

Correct page 332, line 6, for

$$\text{or to } \frac{d\left(\frac{u}{r}\right)}{dr}; \text{ read or } \frac{1}{2}\frac{du}{dr} - \frac{u}{r^2} = \frac{d\left(\frac{u}{r}\right)}{dr};$$

Correct page 332, line 13, for

$$\text{to } \frac{d(ru)}{dr}; \text{ read } r\,\frac{du}{dr} + u = \frac{d(ru)}{dr};$$

Chemistry, Physics, Technology, etc.

INFUSORIAL EARTH AND ITS USES.

By Dr. W. H. Wahl.*

[From the *Quarterly Journal of Science*, for July, 1876.]

Geologists have long since established, beyond peradventure, the fact that there are rocks in the interior of continents, at various depths in the earth, and at great heights above the sea, which are almost entirely made up of the remains of what were once living organisms. Such rock-masses, says Lyell, may be compared with modern oyster beds and coral reefs, and, like them, their rate of increase must have been extremely gradual. But there are a variety of mineral deposits that are now proved to have been derived from plants and animals, of which the organic origin was not suspected even by naturalists. Great surprise was therefore manifested when the late Prof. Ehrenberg announced the discovery that a certain kind of siliceous stone, called tripoli, was entirely composed of the remains of countless millions of extremely minute organic beings. This observation of the famous German microscopist speedily led to the discovery of the fact that deposits of this character were quite abundant, and that they were even being formed at the present time over extended areas. The minute organisms, whose skeletons make up the bulk of the deposits, which are now known under the name of infusorial earth, have been shown to inhabit the ocean in inconceivable numbers, giving rise to the luminosity of the waters, which has been the subject of much discussion, and flourishing in almost every place where water stands for several months of the year. Their indestructible shells are therefore to be found in greater or less quantity in the sedimentary deposits of all our bogs, ponds, and slow streams. They are found in great abundance beneath peat bogs, where they constitute strata, often many feet in thickness and of great extent, almost entirely composed of the siliceous carapaces of

* Editor *Polytechnic Review*, Phila.

organic beings, so inconceivably minute that millions of their remains are found in a single inch. Ehrenberg estimates that about 18,000 cubic feet of these siliceous organisms accumulate annually in the harbor of Wismar, in the Baltic. He has, furthermore, demonstrated that they accumulate in the beds of American and other seas, lakes and rivers.

The deep sea soundings which have lately been conducted in various quarters of the world, and have attracted much popular interest, have shown, likewise, that the impalpable mud or ooze, which is accumulating at great depth in the bed of the Atlantic and other oceans, is made up almost entirely of the mineral skeletons of certain extremely minute organisms. Of these shells, some are calcareous, and appear to be identical with the organisms which abound in the chalk of Europe—the chalk, indeed, is largely made up of such organic remains—while others are siliceous. One of these deposits in the North Atlantic has been traced over a distance of thirteen hundred miles in breadth, and not less than six hundred miles in length.

In peat bogs, swamps, and the like, both of modern and ancient origin, there are often found layers, at times many feet in thickness, and of considerable extent, of a white siliceous paste, which is found beneath the microscope to be made up wholly of the remains of these minute organisms. These deposits, with which this article is chiefly concerned, are designated by geologists with the name of infusorial earth. The substance of which they are composed has generally, when dry, the appearance and consistence of friable chalk, and the remains of which it is made up, and which were formerly referred to microscopic infusoria, are now generally held to be plants, called by naturalists *diatomaceæ*. The remains of these diatomaceæ are of pure silex, and their shapes, as seen beneath the microscope, are various, and form objects, often of extreme beauty. These forms are very marked and constant in particular genera and species, of which many hundreds have been described and classified by Ehrenberg, Bailey, and others, and while many of the fossil forms are identical with living species, others are allied to them; and the so-called infusorial beds are sometimes of marine and sometimes of fresh water origin. The infusorial earth may readily be distinguished from the several calcareous and clayey deposits which it resembles in appearance, by the fact that it does not effervesce in acids, and its ready solubility

in solution of caustic soda or potash. It has long been well known in the arts as a powder for polishing stones and metals. At Bilin, in Bohemia, which is famous for its occurrence, there is a single stratum of this material, not less in some places than 18 feet in thickness, and extending over a large area. This stone, when seen beneath the microscope, is found to consist of the siliceous plates or frustules of the above mentioned diatomaceæ, united together without visible cement, and so inconceivably minute are the particles of which it is composed that, according to Ehrenberg's statement, a single cubic inch, which weighs about 220 grains, contains about 41,000,000,000 of individuals, and a single grain no less than 187,000,000. Other deposits of infusorial earth (kieselguhr), scarcely less extensive, occur in Germany, at Berlin, and at Planitz, in Saxony. It is found near Lüneburg, in a stratum nearly 28 feet in thickness, and again at Kliecken, near Dessau, and in the vicinity of Cassel. In England deposits of considerable magnitude have been found in Surrey, at the base of the chalk hills, and elsewhere. In Ireland there is a celebrated stratum on the banks of the River Bann, in the county of Down, and which, from being in much request for polishing plate, is locally known as Lord Roden's plate powder; another bed is found at the base of the Mourne Mountains, in the same county. In Lapland a similar earth is met with, which in times of scarcity, it is said, is mixed by the inhabitants with the ground bark of trees and used for food. The edible earth of Lillhaggsjon, in Sweden, is of the same nature. The infusorial earth is found in quantity in the Isle of France and at San Fiora, in Tuscany, and deposits of various thicknesses have been detected in Africa (the tripoli of commerce is an infusorial earth that has long been exported from the country whose name it bears), Asia, Australia, and New Zealand. In America it has been found in a great number of localities, and occasionally in enormous quantities. Of this nature are the beds of white earth along the banks of the Amazon, in Brazil, and used occasionally as food (?) by the native inhabitants. They have been detected also in Newfoundland and Labrador. In the United States perhaps the most remarkable deposit is that upon which the City of Richmond, Va., is built; this deposit is, in places, over 20 feet in thickness, and has been traced by Prof. W. B. Rogers, who was the first to point out its nature, from Herring's Bay, on the Chesapeake, Md., to Petersburg, Va.,

and beyond. At Petersburg the stratum is 30 feet in thickness. Beds of the same character and of some magnitude have likewise been found in California, Oregon, and other points on the Pacific, and at West Point, N.Y.; while of less importance are the infusorial beds at Wrentham and Andover, Mass., Smithfield, R.I., Stratford, Conn., and other localities too numerous to mention.

An interesting occurrence of this nature is the deposit of infusorial earth at Drakeville, Morris County, New Jersey, and which, through the instrumentality of the writer and others, was first brought into general public notice about three years ago. The bed in question is on the property of the late Frederick S. Cook, and is located at the foot of Schooley's Mountain. The annual report of Prof. George H. Cook, State Geologist of New Jersey for 1874, contained a descriptive article in reference thereto, from which we obtain the following statements concerning its probable extent, etc.:

"It has been known as a white earth or marl for a long time, and some years since was dug out and spread upon the soil as a manure; it had also been observed to possess remarkable excellence for scouring silver. The establishment of a manufactory for making nitro-glycerine and giant powder at McCainsville, near Drakeville, in which infusorial earth imported from Germany was used, led to an examination of this deposit, when it was found to be the same material with that they were bringing from Europe. The deposit occurs in a depression of the surface just at the foot of the mountain (Schooley's). The swale appears to be occupied in its lowest part by a common swamp of low bushes, growing in wet black earth; but by digging in the black earth it is found to be only about a foot thick, and underneath it is the infusorial earth. The extent of the black ground is about 540 feet in length by 200 feet in breadth, and 100 yards north-east is another but much smaller deposit. A trial pit sunk in the middle of the swale showed a thickness of 12 inches of black earth, 8 inches of very light infusorial earth, and 12 inches or more of a much denser infusorial earth. The lower part is said to be 3 feet thick, but I only examined the upper foot of it."

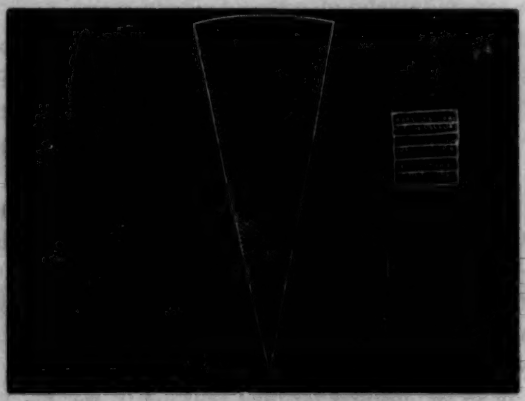
The report continues: "There is little doubt that other deposits will be found in the small ponds and swamps in this gneiss region, and those interested will do well to make search for it in any of the swales where these little swamps occur. It can be easily reached by digging, and when found can be distinguished from any other white

earth by its not effervescing with acids as white marl does, by its not becoming plastic when wet, as white clay does, and by its dissolving almost entirely in a strong boiling hot solution of washing soda.

"The importance of this material will be appreciated when it is stated that the manufacture of *dynamite*, or giant powder, at Drakeville, has reached 50,000 pounds a month. There are different grades of *dynamite*, but some of it contains 25 per cent. of infusorial earth."

An analysis of an average dried sample of the Drakeville deposit yielded the writer 47·12 per cent. of soluble silica.

Concerning the application of this curious substance in the useful arts quite a chapter might be written. During the past few years it has attracted the special attention of practical men, and so many and various have been the uses for which it has been suggested that their



FORMS OF DIATOMS FROM THE RICHMOND DEPOSITS.

bare enumeration may well excite surprise. At least one very important industry of recent origin has been practically created by it, and its employment in others is steadily growing in extent and importance. A summary of the subject in its technical aspects, with brief comments upon the more important items, is given in what follows.

The most popularly known, and perhaps the earliest application of the diatomaceous earth, is its utilization as a polishing agent for stone and metals. For this purpose, when carefully freed from grit and other impurities, its considerable hardness and its wonderfully fine state of division fit it most admirably. It may be applied wet or dry. It is well known in this connection under the name of tripoli,

so called from the locality whence it was originally brought. Under the name of "electro-silicon," "magic-brilliant," and other trade designations, the diatomaceous earth from Nevada and other localities has been extensively introduced as a polish for gold, silver, and plated ware, for which—as for tin, Britannia ware, and other metals used in the household—its wide popularity is the best proof of its excellence.

Being a very poor conductor of heat, it has been suggested and applied for surrounding ice, beer and ale cellars, fire-proof safes, steam-boilers, powder-magazines, refrigerators, etc. The results of certain experiments lately made by Refart and Co., of Braunschweig, to ascertain how this material compared with other substances generally employed for the purpose, are highly favorable to the merits of infusorial earth for this application.

Without entering into the mechanical details of the apparatus employed in these trials, it will suffice to state that in the time required to melt 100 parts (by weight) of ice surrounded by the siliceous earth, 235 parts of ice were melted in a cylinder surrounded with an equally thick layer of dry, light garden earth. Moist earth, and moist materials generally, gave still more unfavorable results. Again, for every 100 parts of ice melted when protected by the infusorial earth, 142 parts of ice protected by dry, sifted coal ashes, were melted. The results obtained with flax-shives were about the same as with the infusorial earth. These trials demonstrated that infusorial silica and flax-shives offer the greatest amount of resistance to the transmission of heat; that dry coal-ashes are far less efficient, and moist ashes still more so; and finally that earth, as compared with these, is very inferior as a non-conductor. The use of the infusorial earth is therefore highly recommended for filling in between the walls, and for covering the mason work in ice-cellars. For this purpose the following additional advantages are urged in favor of this substance, viz.:—It is extremely light,—being nearly five times as light as dry earth, and about half the weight of dry coal ashes,—and it is not combustible, remaining unaffected in the hottest fire. These properties, to quote from the published account of the above trials, "render this substance preferable to flax-shives, tan-bark, peat, sawdust, and similar materials, which are about equal to it in non-conducting quality, but which are combustible, and when kept for some time rot or moulder, shrink and settle, and might under some circumstances, take fire spontaneously" (*sic!*).

The infusorial earth, it is further claimed, will be found highly useful in fire-proof safes, as a surrounding for powder-magazines on shipboard, for covering steam-pipes and boilers, and for all similar purposes. Reference is made in some of the encyclopædias (*vide* "American Encyclopædia," iii, 268) to what are termed floating bricks, which, according to account, are made of infusorial earth, and are named in virtue of their power of floating upon water. Clay is sometimes added to the silica to assist in binding the material together. Such bricks, we are told, were made in ancient times, and were described by Posidonius and Strabo, and particularly commended by Vitruvius, Pollio, and Pliny. In 1791 they were again brought into notice by Giovanni Fabroni, in Tuscany, who, after many trials, succeeded in making bricks which would float upon water. Their strength was but little inferior to that of ordinary bricks; they are remarkable not only for extreme lightness, but also for their infusibility, and for being very poor conductors of heat; they may be held at one end while the other is red-hot. As an experiment, Fabroni constructed the powder-magazine of a wooden ship with these bricks; the vessel being set on fire, sank without explosion of the powder. In 1832 Count de Nantes, and Fournet, a mining engineer, used them in constructing powder-magazines and other parts of ships, thus lessening danger from fire. From an earlier source ("Encyclopædia Americana," ii, 266) we are informed that these floating bricks, made of agaric mineral or fossil farina,—infusorial earth,—have been found, on account of their infusibility at the highest temperatures, to be extremely useful in constructing reverberatory furnaces, pyrometers, and magazines of combustible materials, while their lightness and non-conducting qualities render them particularly useful for the construction of powder-magazines on board of ships.

In agriculture, the use of the infusorial earth has been suggested as a manure for lands poor in silica, which substance enters importantly into the constitution of the stalks and outer coverings of cereals. Quite an animated controversy, indeed, has of late sprung up as to the merits of infusorial silica as a component of fertilizers, an idea which forms the essential feature of a patent lately issued to Messrs. N. and G. Popplein, Jun., of Baltimore. It would be foreign to the purpose of this sketch to enter into a discussion of the merits of this controversy, involving as it does the introduction of certain debatable questions in agricultural chemistry; but the ideas of the Messrs.

Popplein have aroused on the one hand such warm championship, and on the other such opposition, that a concise statement of the points in dispute may not be amiss.

The manufacturers before named, proceeding from the well-known fact that the relative quantity of silica in the ash of the cereals is greatly in excess of what is required for the normal combination with the bases (potash, soda, etc.) found therein, claim that in the ordinary course of things it is impossible for Nature to furnish to cultivated lands for successive years the proper amount of silica in assimilable form for the plant, inasmuch as the liberation of this substance by the chemical decomposition of the mineral matters of the soil containing it, goes on so slowly as to render doubtful the production in many years of the amount required for a single crop. In proof of this assertion they refer to the great reduction in the yield of the wheat crop, since farmers began years ago to sell the straw of the crop that formerly was returned to the soil. For this, and other reasons less obvious, their attention was attracted to the importance of incorporating silica into commercial fertilizers—one difficulty remained to be overcome, namely, the discovery of a form of the silica —which should be assimilable by the plant. This they claim to have found in the infusorial earth,—in which the silica is in an inconceivably minute state of division,—the result of their consideration being the production of a so-called "silicated superphosphate of lime," a superphosphate with which the infusorial earth is intimately incorporated. The argument urging the importance of an abundant supply of silicic acid in available form, as an absolute necessity for the proper nutrition of cereals, is not disputed; and the manufacturers, to demonstrate the availability of the silica in the form in which they employ it, affirm that they have succeeded in proving the highly interesting and novel fact that the very minute skeletons or shells of which the infusorial earth is mainly composed are carried up *as such* into the body of the plant itself. Upon this point the following gleanings from an investigation conducted by Prof. P. B. Wilson will be read with interest:—

This chemist subjected to a microscopical examination the straw from the wheat-fields of Col. J. B. Kunkel, of Frederick County, Maryland, which had been fertilized by the silicated phosphate, his purpose being to make "a more complete investigation into the siliceous structure of the stalk, in determining whether the infusoria

passed directly as such into the sap-cells, to be carried forward by capillary force, and to finally assume their functions,—the formation of the epidermal shield for giving strength to the straw, to withstand the destructive force of high winds and beating rains, as well as a protection against the attacks of parasites."

"In making these investigations thorough precautions were observed, to cleanse the straw from all accidental impurities by washing and gentle friction, not sufficient, however, to destroy the epidermis. The organic matter was then removed by the prescribed methods, aided by my own experience.

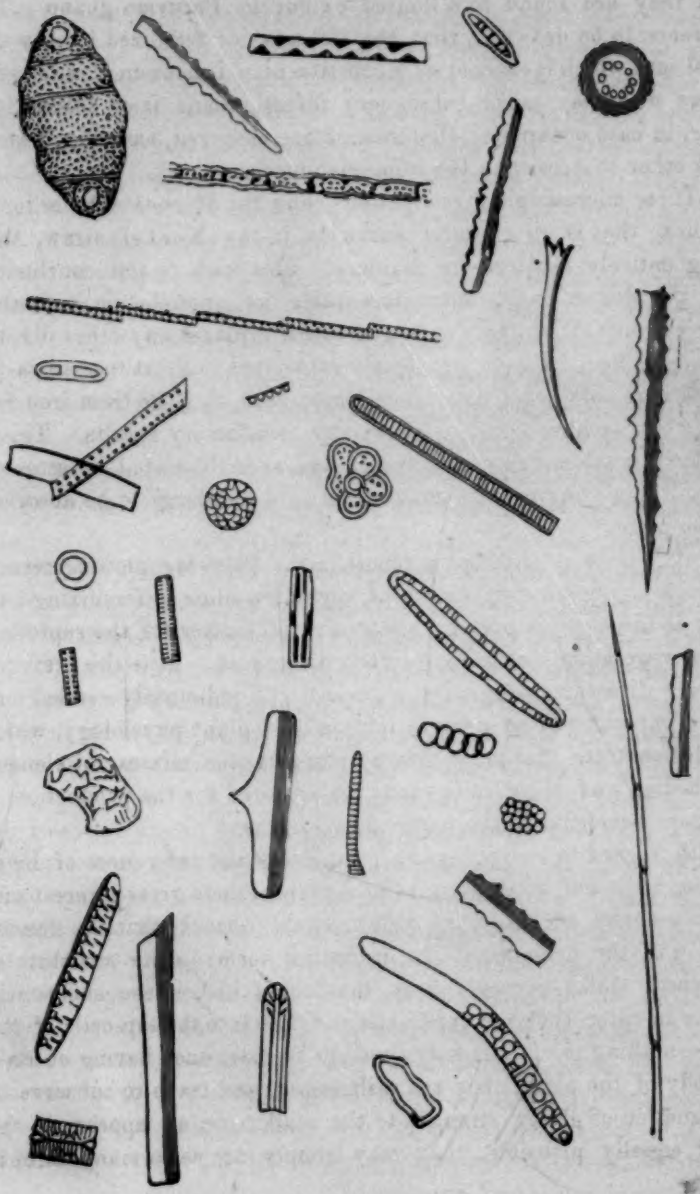
"My labors," he continues, "have been amply rewarded by one of the most enchanting views that has ever fallen to my lot to behold through twenty years of varied scientific investigations. When the epidermal siliceous coating was adjusted upon the field of the microscope, some thirty-six forms of the Diatomaceæ, which I have carefully sketched, were observed (see engraving, magnified 300 diameters) where perfect disintegration has been produced. When the structure to a great extent is retained, a marvelous interlacing of these forms presents itself sometimes side by side, at other times overlapping."

From this very interesting observation, Prof. Wilson advances a number of inferences, which, although the writer is not prepared to accept in full, are of sufficient interest to warrant their reproduction. He affirms that his investigation "overthrows all theories that have ever been advanced, that silica enters into plant structure in combination with the alkalies, the alkaline earths, or the earths proper. Chemical investigation led me to this conclusion some months since, now confirmed by that of the microscope.

"My mind was particularly impressed with the absence of the disc-like form, the *Actinocyclus ehrenbergii* and the *Actinoptychus undulatus* in their perfect state in the straw, while the other forms are common both to the infusorial earth and the wheat. My conclusions are that the varieties mentioned are too large to enter the root capillaries, for on the field of the microscope they have three to four times the magnitude of the others. This I will fully investigate during the coming summer, by making accurate measurements of rootlets and diatoms, when I will be able to obtain stalks of wheat as grown in the fields, preferring this mode of investigation to *pot culture*, to disarm controversy, and to divest the investigation of all semblance of laboratory experiment.

Forms of Diatoms found in Col. Kunkel's Straw.

MAGNIFIED 300 DIAMETERS.



"I have examined various specimens of wheat straw taken at random from the market, but have failed to find a single diatom. This to a certain extent surprised me, when taking into consideration that they are found to a limited extent in Peruvian guano. The inference to be drawn is, that the soil was not fertilized by any material into which it entered as a constituent. I mention this to guide others who may make subsequent investigations from falling into error, in case occasional Diatomaceæ are observed, as being derived from other sources than the infusorial deposits.

"These microscopic investigations show the absence of other forms of silica, that is, in granular particles in the (Kunkel) straw, they being entirely replaced by diatoms. This leads to the conclusion, that the diatom is the more acceptable for assimilation, and when sufficient infusorial remains are present, replaces any other divided form of silica. I have previously attempted to substitute silica for diatoms, as obtained from the decomposition of slags from iron furnaces, but we have failed to derive any satisfactory results. This is due to its combination as a silicate; and when liberated by stronger acids, it agglutinates into masses too hard and large to be absorbed by the plant."

Prof. Wilson concludes his report in the following glowing terms: "I look upon this application of vegetable silica to fertilizing purposes as the most important adaptation of matter for the reproduction of vegetation that has ever been discovered. It is the first step in a new direction, rationally conceived and judiciously carried out. A new impetus will be given to the study of plant physiology, which will demonstrate that more than a heterogeneous mixture of elementary bodies and their compounds are required for the production of the crops beneficial to the requirements of man."

With regard to the foregoing statements and inferences of Prof. Wilson, while not attempting to undervalue their great interest and possible entire accuracy, the writer would remark that the demonstration of the presence of the infusorial forms in the structure of the wheat stalks proves simply that these bodies are sufficiently minute to enter the root capillaries and pass into the sap-cells of the plant—nothing more. It may possibly be that, once having entered the body of the plant, they are assimilated, and made to subserve to the function of giving strength to the stalk; or, as appears to the writer equally plausible, they may simply act as so many minute

mechanical impurities drawn into the circulation of the plant, and, effecting a lodgment wherever they chance, clog up the passages, and thus actually obstruct rather than serve the process of nutrition. To follow the history of one of these forms in a living plant under the microscope, and observe its gradual dissolution, would afford the only method of positively proving the truth or falsity of either of the explanations that have been presented. While not presuming to decide so doubtful a question, it is very reasonable to believe that much of the silica of the so-called silicated superphosphate is made "available" as plant-food in solution as an alkaline salt, in which condition its assimilation by the plant presents no difficulties to the understanding. Dr. Wolf, the excellent State Chemist of Delaware, has kindly furnished the writer the following record of an analysis of the "silicated superphosphate," viz.:—

Soluble Phosphoric Acid,	5·855 per cent.
Precipitated Phosphoric Acid,	3·327 "
Insoluble Phosphoric Acid,	trace.
Silica,	20·568 "
Sulphate of Potassa,	6·173 "

According to the Messrs. Popplein's published formula, the net ton of their "silicated superphosphate" contains:—

Infusorial Earth,	800 lbs.
Dissolved Bone,	800 "
Potash Salts,	400 "

As an absorbent and carrier of liquids of various kinds, and especially as a carrier of nitro-glycerin, the infusorial earth has been found to be most excellently adapted. It takes up from three to five times its weight of water, oil, nitro-glycerin, etc. It would doubtless prove equally valuable as a carrier of carbolic acid and other disinfectants, as a disinfecting powder, and has possibly already found application for this purpose.

In order to bring nitro-glycerin within the range of articles of transport, Nobel, who first demonstrated its value in the arts, devised the production of a powder now so extensively employed under the name of dynamite, in which the explosive oil is simply carried by the inert, pulverulent siliceous earth. The process of the preparation of dynamite may be described as follows:—

The infusorial earth must first be freed from water, organic substances, and mechanical impurities (sand, etc.). The first two are

removed by calcining at a red heat in an oven with several shelves, one above the other, on which the earth is placed and slowly pushed from the upper to the lower. The organic matter, which is considered dangerous to the stability of the dynamite, is thus burned out. It is then pressed with hard rollers and sifted, which separates it from the larger particles and grit. It is now ready for use.

Fifty pounds of infusorial earth are put into flat wooden tanks and covered with 150 pounds of nitro-glycerin, when the workmen mix them with the naked hand. Gloves of india-rubber were at first provided, but the workmen preferred to knead the mixture with the free hands. In half an hour the incorporation of the oil with the earth is complete, and the dynamite is ready for filling in the cartridge moulds. The cartridges are simple cylinders, protected by parchment paper. If ordinary paper is used the oil soaks into it, and there is great danger of premature explosion. Dynamite is a brownish gray, sometimes reddish, inodorous, pasty, greasy mass, having the specific gravity of 1·6. When ignited by an ordinary flame, it burns up quickly without detonation, and must therefore be fired with a patent exploder containing fulminate of silver inclosed in a copper capsule. It requires a heavy blow of a hammer on an anvil to explode it, and even then only the portions struck are fired. In this respect it presents great advantages over nitro-glycerin, which is easily exploded by percussion. On the other hand, the wood of the boxes in which dynamite is packed becomes by slow degrees impregnated with nitro-glycerin, and forms a most dangerously explosive material, which may give rise to serious accidents in warehouses where it is stored. As long as the nitro-glycerin is confined in the infusorial silica there appears to be very little danger, but the escape of a few drops of the oil may be the source of great mischief. The force exerted by the dynamite is much greater than that of gunpowder, and under the name of giant powder it has been largely employed in the mines of California. Other explosives, such as dualine and lithofracteur, may be said to be varieties of dynamite, having nitro-glycerin for their base, and using saw-dust or some other substance as an absorbent. All of them are powerful explosives, and must be handled with care.

For the preparation of cements and of artificial stone, a number of processes have been devised, in which infusorial earth plays a prominent part, viz.: Equal parts of infusorial silica and litharge, and

one-half part of slaked lime, stirred into a paste in linseed oil, is affirmed to become as hard as sandstone on setting, and is recommended as an excellent compound for cementing stone, metal, and wood. The following recipe, again, is pronounced to be serviceable for the production of an artificial stone for art objects. For this purpose the infusorial earth is intimately mixed with well pulverized, freshly burned lime, in the proportion of from three to six parts of the former to one of the latter. The mixture is then pressed into moulds under an addition of a very slight quantity of water. The resulting product, a silicate of lime, is formed with the evolution of considerable heat. The objects produced ultimately attain great hardness; they are perfectly water-proof, and may readily be colored with any color used in stereochromy.

In combination with sulphur, infusorial earth forms a plastic mass, called zeiodelite, but no uses have yet been made of it.

By far the most important application of infusorial earth in this direction, however, has been successfully accomplished by Mr. Fred. Ransome, of England, in the production on the large scale of an artificial stone for general purposes, to which he has given the name of apoenite. The so-called "Ransome stone," invented by this gentleman, is made by thoroughly incorporating sand and silicate of soda in a mixing mill, moulding into the form required of the block, and then saturating the same with a solution of chloride of calcium, either by exhausting the air with air-pumps, or by forcing the solution through the moulded mass by gravitation or otherwise. The result is the formation of an insoluble silicate of lime, which firmly cements the particles of which the mass is composed, and of chloride of sodium or common salt, which is subsequently removed by the free application of water. The process of washing to remove all traces of the salt from the Ransome stone, which is necessary to prevent its efflorescence and secure its proper cementation, was found to be in many cases so tedious, expensive and objectionable, that the inventor, after many experiments, devised the following process, in which the use of chloride of calcium is avoided. Mr. Ransome mixes suitable quantities of lime (or substances containing lime) and soluble silica (*i. e.*, infusorial earth) with sand, and a solution of silicate of soda or potassa, which, when intimately incorporated, are moulded as before, and allowed to harden gradually, as the silicate of lime, produced by the action of the lime on the silicate of soda, is formed.

As rapidly as the soda (or potash) of the water-glass solution is set free, it dissolves some of the infusorial silica, and again gives it up to the lime to form more cement, acting thus as the carrier of silica to the lime, until eventually all the lime is combined. In the course of the successive changes that take place, a portion of the free alkali appears to be bound at each step with the lime, as a compound silicate; and as the result of these several changes the whole of the alkali is gradually fixed, thus leaving nothing to be washed out. The mass gradually becomes thoroughly indurated, and in a very short time is converted into a very compact stone—apoenite—capable of withstanding enormous pressure, and increasing in strength and hardness with age.

In combination with magnesite (carbonate of magnesia), infusorial earth forms what is described as an excellent cement, which is manufactured in Germany, and sold under the name of "albolite."

In pottery the infusorial earth has received several important applications. When fused, for example, with borate of lime, as such is obtainable in the trade under the name of boronatrocalcite or tincalzite, an excellent glazing is produced (*Manufacturer and Builder*), which is not only useful for furnaces and pottery of all kinds, but also for enameling iron and slate, being free from lead and not apt to crack off. By fusing a mixture of infusorial earth (freed from sand) with borate of magnesia (stassfurtite), a kind of "hot-cast porcelain" is produced, having great durability and beauty. For this purpose the infusorial earth requires to be perfectly dry and free from lumps. It is introduced into the crucible in small portions and under constant stirring, until the fused stassfurtite ceases to take up more. The mass may be cast like glass, and if very liquid it may even be blown, and is thus fitted for an extensive application (*ibid.*).

Bœttger publishes the observation that when an alcoholic solution of any of the coal-tar colors is mixed with a sufficient quantity of infusorial earth, water added, and the mixture filtered, the liquid will run off clear, while the earth retains all the pigment. Hitherto the compounds of alumina have been used for the production of the so-called lakes, and it is quite probable that the above noted behavior of this material may find important applications in the arts.

The use of infusorial earth has been suggested in glass making as a substitute for sand; but it appears not to be well suited for this

purpose, the reason assigned being that it swells too much in the crucible. In the manufacture of soluble glass (water glass), for which it has likewise been tried, the impurities it contains—clay, phosphate of lime, etc.—have been found to render it somewhat unsuitable.

To conclude a sketch which has unwittingly taken considerable proportions, the following enumeration will suffice to show that the subject is by no means exhausted: A compound called diatite, devised by Merrick, consists of gum-lac and infusorial earth. The siliceous earth has been added to sealing-wax to prevent its running; it is sometimes added to paper to give it body; and to soap for the same purpose, and to add to its detergent qualities (?); and it is said to form an excellent addition to rubber, for certain uses of the latter; its addition to modeling clay is said to prevent it from cracking in moulding; and lastly, though doubtless many real or suggested applications of this curious substance have been overlooked, it is said to be of use in the manufacture of smalt and ultramarine.

ON THE DEVELOPMENT OF THE CHEMICAL ARTS DURING THE LAST TEN YEARS.*

By Dr. A. W. Hofmann.

From the *Chemical News*.

[Continued from Vol. cii, page 360.]

It has been observed that when iron apparatus is employed for generating and conducting the hydrochloric acid gas this conveys along a certain quantity of ferric chloride, from which it cannot be freed before entering the decomposing furnace. Here the iron is deposited either as chloride, or, if the formation of chlorine has already begun, *i.e.*, as soon as watery vapor is mixed with the gases, as pulverulent oxide of iron upon the copper-sulphate. This iron dust falls from the vertical drain-pipes through the grating into the space below, whence it is easily removed. It may here, however, be remarked that Deacon, according to private communications, has latterly omitted the partition walls from the decomposition furnace, by which he effects a more

* "Berichte über die Entwickelung der Chemischen Industrie Während des Letzten Jahrzehends."

ready movement of the gaseous current without any disadvantage. In a Deacon's apparatus, which the author has seen at work in the establishment of Kunheim, at Berlin, the partition walls and the vertical drain-pipes had both been omitted without any detriment being observed in the course of several months' working.

After the mixture has passed through the decomposing furnace it consists of chlorine, water, nitrogen, superfluous oxygen, and unconsumed hydrochloric acid. The latter is condensed in an ordinary condensation apparatus, charged with dilute hydrochloric acid, or water, the temperature of the gases having been previously reduced by air-coolers. The gas is next freed from the accompanying water by passage through a tower filled with chloride of calcium, or, better, through a coke-tower, down which sulphuric acid flows. The gaseous mixture is then fit for absorption in the chloride of lime chambers. As a matter of course a drying apparatus is superfluous if a watery liquid is to be saturated with chlorine, as in the preparation of potassic chlorate.

For the latter purpose Kunheim utilizes the chlorine obtained on Deacon's method. The chlorine is here so completely absorbed by the milk of lime through which it passes that mere traces are contained in the air escaping from the exhauster. The draft in the entire apparatus is kept up by any aspiratory arrangement beyond the chloride of lime chambers and measured by an anemometer constructed by Hurter. The latter consists of a U-tube of 5-16ths c. m. internal diameter, with legs about 25 c. m. in length. As one leg of this tube is always in communication with the gaseous current, the pressure occasioned by the current is always shown in the other leg by the tube by the displacement of a liquid therein contained (ether). The U-tube is fixed so that the leg containing the liquid lies flat on a graduated inclined plane, which may be raised or lowered on a frame fitted with a level. The meniscus of the liquid is thus extended diagonally, and the small vertical divisions of the scale are magnified into long horizontal degrees. Kunheim uses a simple upright U-tube filled with ether.

The greatest practical difficulty in the Deacon's chlorine process lies in the enormous volume of gas which has to be dealt with, and consequently in the large dimensions required for the chloride of lime chambers. But Deacon has endeavored to combat these difficulties. He compels the gases to take such a course that they are systemati-

cally deprived of chlorine. They meet at first with chloride of lime almost saturated, then, as they lose their chlorine they pass over lime less and less chlorinized till they finally pass out into the atmosphere completely exhausted over fresh hydrate of lime. The arrangements by which this systematic saturation of the lime is produced are of a twofold nature. In the first place chambers are employed in which the lime lies on gratings and which are so connected with each other that the chlorine streams through them successively. As soon as the lime in the chamber nearest the generating apparatus is saturated it is thrown out of connection with the current of chlorine, is charged with fresh lime, and takes its place at the end of the series, whilst a chamber containing lime nearly saturated receives the concentrated portion of the gaseous current. The second kind of methodic saturation is the following, in which is applied the principle of Hasenclever and Helbig's pyrites furnace:—

In a tower are several stories of sloping plates of slate, forming a smaller angle with the perpendicular than the outer surface of the heaped up chloride of lime is capable of taking. In every story the direction of the plates, which are parallel to each other, cuts the plane of the plates, likewise parallel to each other, in the next higher and next lower story. Thus intervals are produced which extend in zigzag from below upwards. At the lower end of each of these intervals is a shovel-wheel by whose revolution the speed of a powder sliding over the plates can be regulated. Into this tower the lime is thrown by means of a hopper and slips from plate to plate till its further fall is stopped by the rollers. But as the falling lime cannot form so acute an angle with the perpendicular as the plates it does not completely fill the interstices, but leaves in every link of the zigzag a wedge-shaped space, through which the gases are compelled to ascend from stage to stage. Hence, as the lime moves constantly downwards in an opposite direction to the current, fresh lime enters above, and saturated chloride is taken out below. To obviate incidental stoppages in the motion of the lime there are here and there in the tower openings fitted with valves. This apparatus can scarcely be adopted in practice, as chloride of lime, from its tendency to clog together, moves but slowly down an inclined plane, whence frequent stoppages would be inevitable.

The last mentioned apparatus, suitably modified, is recommended by Deacon for the preparation of salt-cake from diluted chlorine,

sulphurous acid, steam, and salt. Instead of lime he causes salt to glide down a tower strongly heated, whilst a mixture of diluted chlorine, sulphurous acid, and steam ascends.

The hydrochloric acid thus formed is condensed and re-converted into chlorine, whilst the sulphuric acid formed by the oxidation of the sulphurous acid converts the salt into sulphate.

When Deacon's process was first made known, its industrial practicability was strongly doubted. The principal difficulties were considered to depend on the regulation of the temperature, the enormous volume of gases to be dealt with, and the considerable consumption of fuel. Since, however, the two former obstacles have been overcome by the inventor in the manner described, the process seems more and more available. In Great Britain at least thirteen establishments are already working on the new process, and in Germany two (Kunheim and the Rhenania, the latter experimentally). According to Deacon's statement more than 1,000 kilos. of chloride of lime at 35 per cent. are obtained from 1,500 kilos. of salt, with a consumption of 1,000 kilos. small coal. A small portion of the hydrochloric acid gas is lost from causes not as yet fully ascertained, but the portion which passes undecomposed through the apparatus is entirely recovered.

Besides Deacon's process several other proposals have been made for obtaining chlorine, and in some cases without the use of manganese, but they have not been adopted in practice.

Thus Macfarlane*[1] hoped to obtain soda and chlorine simultaneously by passing air over an ignited mixture of copperas and salt. Sulphate of soda and ferrous chloride are formed, which latter is converted into iron oxide and chlorine by the oxygen. The mixture of sulphate of soda and oxide of iron on reduction with coal and lixiviation with water yields sodium hydrate (easily convertible into soda) and iron sulphide, which is reconverted into copperas on exposure to the air. Clemm*[2] endeavored to use chloride of magnesium for the preparation of chlorine; he mixed the magnesium chloride with manganese and decomposed it by a current of superheated steam.

Chloride of lime, the only form in which free chlorine is found in the market, has latterly been the subject of a number of published

*[1] Macfarlane, *Dingl. Pol. Journ.*, clxxiii, p. 129.

*[2] Clemm, *Dingl. Pol. Journ.*, clxxiii, p. 127.

papers, which have not led to any material change in the manner of its preparation. The causes of its spontaneous decomposition, sometimes attended with explosions, and formerly not infrequent, have been investigated. To avoid such misfortunes it is recommended not to saturate the lime when too hot, and not to carry the process to the uttermost attainable point, and also not to pack it in barrels when still too recent and too moist. The gas which occasions the explosion of the chloride of lime casks has been found to be oxygen, and on such spontaneous decompositions the mass of the compound is converted into a mixture of chloride and chlorate of calcium. Interesting dissertations of a more scientific character concerning the nature of chloride of lime have been published by Kolb, Riche, Bobierre, Scheurer-Kestner, Tschigianjang, Fricke and Reimer, Crace-Calvert, and Göpner, which unfortunately cannot be reported on in brief, as the results of these researches are in part, at least, contradictory. The final solution of the question as to the constitution of chloride of lime is by no means solved.

Potassium Chlorate.—No important change in the manufacture of the chlorate of potash has been introduced in the last few years. Now, as well as formerly, it is everywhere made according to Liebig's original process, hot milk of lime being saturated with chlorine, and the calcium chlorate, formed simultaneously with calcium chloride, being decomposed by potassium chloride.

In England, which produces the bulk of the chlorate of potash of commerce, it is at present, according to Lunge, obtained in the following manner:*

For saturating the milk of lime are employed two iron cylinders, lined with lead, connected with each other, and fitted with agitators. These cylinders communicate with each other, and with the chlorine still by means of tubes, and in such a manner that the contents of the one approach the state of complete saturation, whilst in the other any chlorine which may have escaped absorption is taken up by fresh milk of lime. As soon as perfect saturation has been attained in the first receiver, its contents are replaced by fresh milk of lime, and the current of chlorine is turned so that it may first enter the second apparatus. The solution of chloride and chlorate of calcium thus obtained has a rose-red color, due, according to some authorities, to permanganic acid; but which, according to others (Crace-Calvert),

* Lunge, *Dingl. Pol. Jour.*, cxxcix, 489.

appears also in the absence of manganese. In fact, this rose color of the liquid is observed also as a sign of the complete saturation of the liquid where the chlorine employed is obtained without the use of manganese as at Kunheim's works at Berlin, where chlorine obtained by Deacon's process is used in the preparation of chlorate. The red liquid after clearing with chloride of potassium is evaporated down to the sp. gr. 1·28 and allowed to crystallize. The liquid drawn off from the first crop of crystals is further evaporated down to 1·35, when a second smaller quantity of chlorate of potash is obtained. A portion, about 12 per cent. of the chlorate of potash remains in the mother liquor, which can therefore be treated as a source of chlorine. The crystals obtained are still contaminated with chloride of potassium and iron. To remove these impurities the crude salt is dissolved in the smallest possible quantity of hot water, 2·5 kilos. of soda are added to 10 hectolitres of the solution, and after the carbonate of lime and oxide of iron have been deposited it is allowed to crystallize. The crystals are dried in drying-rooms; the larger ones are sold without further treatment, and the smaller ones are ground between rollers. This process, in spite of every care, is sometimes attended with explosions. Lunge therefore recommends to crystallize the salt with constant agitation, and thus obtain it as a crystalline powder. In this manner the purification might also be more readily effected, as easily-soluble salts could be removed from the crystalline powder by merely washing with water.

Whilst considerable quantities of chlorate of potash are manufactured in England, this branch seems to be scarcely remunerative in Germany, where the same method of preparation is adopted. Several establishments have recently abandoned the manufacture. According to the experiments of F. Hobrecker, 100 parts of chlorate of potash require—4481·0 hydrochloric acid (20° B.); 772·0 manganese (65 per cent.); 418·0 lime; 72·7 chloride of potassium (92 per cent.); 2262·0 lignite.

Bromine.—However considerably the production of bromine had increased in the earlier decennial periods of its manufacture on the large scale, and however easily vast quantities of this body could be made available for the arts, its industrial applications, and consequently its production, have increased very little in the last few years. Whilst formerly the raw material for its preparation was derived from the mother-liquors of salt springs and from sea-water, especially

that of the Dead Sea, which, though richly bromiferous is too remote from the centres of consumption for chemical products, a new source has been discovered in the mother-liquors of the clearing salts (Abraum salz) of Stassfurt, which can be easily adapted to the demand. In spite of the quantity of bromine which can be obtained at Stassfurt it is merely a by-product of the potash trade, as, in consequence of the small demand and low commercial value, the cost of production falls little short of the market price. The utilization of the Stassfurt "abraum" salts as a source of bromine dates from the year 1865, when A. Frank introduced this branch of industry in order the better to compete with the potash from kelp and from salt-springs, and also in the hope of superseding the use of iodine in the manufacture of colors.

When, in consequence of the extensive opening of manufactories for the utilization of the "abraum" salts, an over-production of the salts of potash occurred, other establishments felt induced to enter upon the preparation of bromine, but without accomplishing anything worthy of note in this direction.

Rich sources of bromine were also discovered in North America, and have been worked with great success.

The product, however, does not arrive in Europe as liquid bromine, since ships do not generally receive it among their cargo. It is exported chiefly as bromide of potassium. But considerable as is the quantity of bromine produced in North America there is no foundation for the fear that it may occasion any appreciable depression of the Stassfurt trade, since bromine is obtained in America as a main product, whilst in Stassfurt it plays merely the part of a by-product of the potash manufacture.

The demand for bromine and its compounds depends on its applications in medicine, photography, and scientific chemistry. The hope of seeing its hydrocarbon compounds extensively employed in the manufacture of coal-tar colors in place of the corresponding iodides has not been fulfilled, in spite of the present greatly increased price of iodine. One obstacle which stood in the way of the application of brom-ethyl and brom-methyl for the purpose in question, *i.e.*, the great volatility of these compounds, has been overcome by Dr. A. W. Hofmann,* who proposes to cause bromamyl—which boils at the far higher temperature of 120°—to act upon the colored bases, to be

* A. W. Hofmann, *Ber. Chem. Ges*, 1869, 441.

ethylated or methylated simultaneously with methylic or ethylic alcohol, thus forming brom-ethyl or brom-methyl along with amylic alcohol. Still the small reactive power of the bromides as compared with the iodides, the inferior brilliance of the colors produced with the aid of the former, the difficulty of recovering the bromine as completely as iodine in consequence of its volatility, have prevented bromine from effectively competing with iodine in this department. Still the hope that bromine may on further investigation attain importance in tinctorial chemistry has not been abandoned. Certain manufactories, both English and German, use a mixture of brom-ethyl, which boils at about the same temperature as iod-methyl and brom-methyl. The reporter is informed on good authority that the color works of Huddersfield and of Barmen still draw large supplies of bromine from Stassfurt.

The use of bromine as a disinfectant in the form of an aqueous solution, introduced during the North American and Franco-Prussian wars, has remained very limited, although it possesses several advantages as compared with chloride of lime. In hospitals the use of bromine occasions much less irritation in the respiratory organs than that of chlorine.

Although, as has been stated, bromine finds scarcely any application in great manufacturing operations, its production is still important, as appears from the report of Chandler.*[1] According to this authority 62,500 kilos. were annually obtained in North America alone in 1869 and 1870, principally in Tarentum, Sligo, Natrona, Pomeroy, Ohio, and Kanawha. Stassfurt produced in the year 1873, 20,000 kilos.; and England and France together about the same quantity.

From the foregoing it will be readily inferred that there is little novelty in the methods of extracting bromine.

Leisler*[2] took out an English patent for a method of obtaining bromine and iodine. He decomposes the bromiferous lyes with a mixture of hydrochloric acid and bichromate of potash in an iron still furnished with a capital of lead or stoneware. The vapors of bromine along with water are led into a receiver containing iron turnings. Bromide of iron is formed, which dissolves in the water, and is either converted into other metallic bromides by the customary

*[1] H. Chandler, *Chemical News*, 1871, No. 586, p. 77.

*[2] L. Leisler, *Dingl. Pol. Journ.*, clxxix, 386. *Wagner Jahresbericht*, 1866, 179.

methods, or is treated for free bromine with sulphuric acid and bichromate of potash. This process has never been reduced into practice, and for Germany at least appears too expensive.

In Stassfurt, therefore,*[1] the method has been followed which had been used for the extraction of bromine in the salt works of Schönebeck, Artern, and Neusalz, consisting of the following operations: The mother-liquor of carnallite at 35° B. freed as far as possible from chloride of calcium by refrigeration, is concentrated to 40° B. by further evaporation. According to Frank the concentration cannot be carried so far, as, in consequence of the partial overheating of the lye at the bottom of the pan, bromine is inevitably wasted in the form of hydrobromic acid. On cooling to 25° a quantity of chloride of magnesium, $MgCl_2+6H_2O$, and the remaining mother-liquor contains from 0·3 to 0·5 bromine as bromide of magnesium. It is placed in a sandstone apparatus resembling those used for the preparation of chlorine with the corresponding quantity of manganese and hydrochloric acid, and heated by the introduction of a current of steam. The red vapors which are evolved about a quarter of an hour after the steam is turned on are condensed in a lead worm, cooled in water, and are collected as liquid bromine in Woolff's bottles. The crude bromine is re-distilled in glass retorts for further purification. A sand-stone apparatus can be charged six times in twenty-four hours. In order to obtain the bromine free from chlorine it is agitated with a solution of bromide of potassium, from which bromine is liberated equivalent to the chlorine present, whilst chlorine of potassium is formed (Falières).

As leaden worms are very rapidly destroyed by liquid bromine, though very slightly attacked by bromine vapors, Frank*[2] employs condensing tubes of earthenware. To separate the bromine from the chloride of bromine simultaneously evolved he avoids a too perfect refrigeration, and conducts the more volatile products, including the chlorine, into a receiver charged with iron turnings or with potash lye. The crude bromine in the first receiver is then completely freed from chlorine and from sparingly volatile organic bromides which are usually present by fractionated distillation.

Several methods for obtaining the bromides of the alkalies and alkaline earths deserve notice. Henner and Von Hohenhausen*[3]

*[1] F. Michel, *Wagner Jahresbericht*, 1867, 194.

*[2] Private communication.

*[3] Henner and Hohenhausen, *Dingl. Pol. Journ.*, clxxiii, 1864, 221.

prepare the bromides of calcium, barium, and strontium by diffusing the respective hydrates in water, decomposing with bromine, evaporating till the formation of crystals begins, and mixing the liquid with alcohol, which precipitates the last portion of the bromate formed. The bromide is then obtained from the liquid, and a further portion is procured by heating the bromate with charcoal. C. Wendler*[1] proposes to prepare the bromides of the alkaline earths according to Rud. Wagner's approved method for the manufacture of the corresponding iodides, *i. e.*, by the action of bromine upon the sulphites.

According to A. Faust*[2] Bœdeker obtains the bromides as follows: Bromide of sulphur is prepared from 20 parts flowers of sulphur and 240 parts of bromine, and gradually poured into the milk of lime made from 140 parts of quicklime, or into a corresponding solution of baryta. The bromide of sulphur in contact with the hydrate of the alkaline earth is decomposed into a metallic bromide and a sulphate. The latter is removed by the addition of alcohol and subsequently of lime. The solution of calcic or baric bromide can either be used for obtaining those salts, or for preparing the sodic, potassic, or ammonic bromide by decomposition with the corresponding carbonate or sulphate.

Casthelaz*[3] prepares the bromide of sodium by forming, in the first place, bromide of ammonium by dropping bromine into liquid ammonia, and decomposes this by the addition of an equivalent quantity of caustic or carbonated soda.

Falières points out*[4] that iodine present in bromide of potassium may be removed by agitation with free bromine.

Of all these methods of preparing bromides, especially bromide of potassium, which is most in use, none is practiced on the large scale. Either the ferroso-ferric bromide is decomposed by the addition of carbonate of potassa, or vapors of bromine are conducted into potash lye, and the potassic bromate formed along with potassic bromide is decomposed by ignition with charcoal powder. The preparation of bromide of potassium and the bromides of iron is conveniently combined with the manufacture of bromine. Since 1867 Frank condenses bromine

*[1] C. Wendler, *Wagner Jahresber.*, 1863, 291.

*[2] A. Faust, *Archiv d. Pharm.*, clxxxi, 216. *Wagner Jahresber.*, 1867, 196.

*[3] Casthelaz, *Monit. Scient.*, 1870, 65. *Chemical News*, 1870, No. 532, 58; and 547, 238. *Wagner Jahresber.*, 1870, 195.

*[4] Falières, *Wagner Jahresber.*, 1872, 274.

in a set of three Woolff's bottles, the first of which slightly cooled, receives liquid bromine, whilst the second contains bromide of potassium or ferrous bromide, and the third potash lye or iron turnings. The chloriferous bromine vapors escaping from the first slightly cooled receiver pass through the solution of bromide and are freed from their chlorine, in the place of which bromine escapes from the bromides and arrives in a pure state into the iron turnings or the potash lye contained in the third bottle, in which pure bromides are at once obtained.

We have already mentioned that a large proportion of bromide of potassium is obtained from the ferroso-ferric bromide. The manufacturers of bromide of potassium are not under the necessity of preparing the iron compound themselves from condensed bromine. It is obtained at the Stassfurt bromine works, and is sold in the form of a paste containing from 65 to 70 per cent. of bromine. As it can be packed in vessels of stoneware and tinned iron and even in wooden casks, it is the most convenient form for the carriage of bromine, which in the free liquid state, is difficult to pack and dangerous to convey.

We may here also mention the bromiferous artificial saline mixtures prepared in imitation of the salts obtained from mineral springs.* At Vienna the mother-liquors and their salts of Kreutznach, Kœsen, Wittekind, &c., were exhibited by Frank, and by the United Manufactures of Leopoldshall. Finally, we must mention the arrangements adopted for preserving the workmen from the injurious action of bromine. It appears in fact, that when these are applied no danger to health is to be apprehended. In the selection of workmen it is primarily essential to see that they have well-developed respiratory organs, and are free from any predisposition to asthma and catarrhal affections. The use of spirituous liquids must be strictly interdicted, as the irritability of the mucous membranes which they produce is exceedingly dangerous. On the other hand, a generous diet is recommended, and especially the abundant use of fatty and mucilaginous articles, butter, bacon, &c.

(To be continued.)

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* In Germany such saline mixtures are used under the name of "bath salts" (*bade-salze*).

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(To accompany detailed Report of Experiments with "Gallatin." For detailed results of experiments with the other steamers see text.)

1	2	3	4	5	6		7	8	9	10	11	12	13	
NAME OF STEAMER.	TYPE OF ENGINE.	DIMENSIONS OF CYLINDERS.	APPROXIMATE STEAM PRESSURE.	MANNER IN WHICH ENGINE WAS OPERATED.	DESIGNATION OF EXPERIMENTS.		AVER. STEAM PRESSURE IN BOILERS.	AVERAGE VACUUM IN CONDENSER.	AVERAGE CUT-OFF IN FRACTIONS OF STROKE.	RATIO OF EXPANSION.	DURATION OF EXPERIMENTS.	AVERAGE REVOLUTIONS PER MINUTE.	AVERAGE MEAN EFFECTIVE PRESSURE IN CYLINDER.	
					No. of Series.	No. of Experiments.	Lbs.	Ins.			Hours.		Lbs.	
		Inches.	Lbs.											
RUSH.	Compound. Connected at right angles. Cylinders Jacketed.	L. Dia. 28. Str. 27. S. Dia. 24. Str. 27.	70	Steam Jackets in use. Weighing coal	I	1	69.1	26.5	S. .36 L. .47	6.22	55.00	70.840	S. 29.685 L. 12.725	S. B.
			40	Steam Jackets in use	I	2	36.7	26.2	S. .60 L. .53	4.03	6.00	55.475	S. 18.882 L. 12.300	S. B.
DEXTER.	Non-compound. Unjacketed.	Dia. 26. Stroke 36.	70	Coal weighed during run No. 5	I	3 4 5 6	68.7 69.3 67.1 66.4	25.9 25.2 25.4 25.3	.18 .23 .25 .33	4.46 3.67 3.49 2.72	2.92 1.42 34.50 .65	56.497 64.306 61.064 72.820	34.439 37.127 37.538 42.028	
			40		I	7 8 9	40 6 39.9 41.9	26.1 26.0 25.5	.26 .38 .45	3.34 2.42 2.08	1.32 1.20 .92	50.848 55.250 60.691	25.583 30.665 33.838	
DALLAS.	Non-compound. Unjacketed.	Dia. 36. Stroke 30.	35	Coal weighed during run No. 12	I	10 11 12 13 14	35.4 35.3 32.0 33.7 27.4	26.1 26.0 25.2 25.4 24.8	.13 .20 .26 .29 .39	5.07 3.89 3.13 2.94 2.32	1.52 1.55 31.00 1.60 1.53	48.681 56.925 61.519 64.479 63.467	18.521 21.447 23.525 24.611 24.126	
GALLATIN.	Non-compound. Jacketed.	Dia. 34.1. Stroke 30.	12 1-2	Steam Jacket not in use	II	1 2	14.6 12.8	25.5 25.0	.46 .64	2.01 1.51	1.92 2.25	40.052 40.867	15.825 16.078	
				Steam Jacket in use	II	3 4	15.4 13.1	25.1 24.9	.47 .65	2.00 1.49	2.10 2.13	41.262 42.453	16.822 16.798	
				Steam Jacket in use and supplied with steam at 70 lbs. pressure	II	5 6	13.4 13.9	26.0 25.5	.52 .63	1.80 1.54	2.22 2.20	41.112 42.273	15.890 17.738	
			40	Steam Jacket not in use—Throttled	II	7 8 9 10 11 12 13*	44.8 40.9 43.3 39.4 39.5 37.7 39.0	25.9 26.1 25.9 23.6 25.9 22.7 24.6	.11 .14 .22 .27 .33 .41 .69	5.92 5.21 3.73 3.16 2.72 2.23 1.41	1.77 1.98 2.05 2.10 2.32 2.17 2.57	43.000 44.235 50.772 50.143 56.022 55.754 52.682	20.816 20.953 26.153 26.501 30.816 30.90 30.35	
				Steam Jacket in use	II	14 15 16 17 18 19 20 21	45.4 42.8 41.6 43.9 41.3 40.0 36.2 37.4	26.1 26.5 25.6 26.6 25.8 24.6 26.4 24.8	.10 .14 .15 .17 .22 .25 .38 .42	6.08 5.07 4.82 4.49 3.71 3.32 2.40 2.21	2.02 2.05 2.20 2.22 2.03 3.75 2.08 2.30	44.322 46.057 45.876 50.308 49.205 51.151 54.528 58.246	19.90 21.69 21.67 23.64 24.61 26.3 28.4 31.9	
			70	Condensing without vacuum—Steam Jacket not in use	II	22 23	70.7 66.2	1.0 1.7	.18 .24	4.37 3.48	2.20 2.22	46.697 51.677	26.4 28.8	
				Condensing without vacuum—Steam Jacket in use	II	24 25	69.7 67.4	1.0 1.7	.20 .24	4.07 3.52	2.05 2.12	49.471 53.236	27.1 29.4	
				Link hauled up—Steam Jacket and Independent Cut-off not in use	II	26	63.8	24.7	.36	2.47	1.92	61.983	35.	
				Link hauled up—Steam Jacket in use—Using Independent Cut-off	II	27 28	69.6 59.9	26.0 25.3	.24 .38	3.45 2.37	2.07 1.95	58.613 60.949	32. 33.	
				Link hauled up—Steam Jacket in use—Not using Independent Cut-off	II	29 30*	69.6 60.4	25.9 25.8	.15 .20	4.90 4.01	2.50 2.05	60.247 60.179	34. 34.	
				Steam Jacket not in use—Draining steam-chest	II	31 32	71.2 67.0	25.8 25.4	.15 .21	4.87 3.83	1.87 2.03	58.464 61.582	31 33	
				Steam Jacket in use—Supplied direct from boiler	II	33	64.0	25.3	.17	4.46	23.95	60.502	33	
				Steam Jacket not in use—Weighing coal	II	34* 35 36 37*	71.5 68.2 68.5 61.1	25.2 25.1 25.9 25.8	.07 .12 .15 .18	7.78 5.63 4.94 4.25	2.18 2.05 2.02 1.98	52.351 56.016 59.868 59.454	2 3 3 3	
				Steam Jacket not in use—Weighing coal	II	38	65.4	25.3	.17	4.50	23.98	61.537	3	
				Steam Jacket in use—Weighing coal	II	39 40* 41* 42* 43	71.6 71.8 69.9 68.2 67.2	25.7 25.4 25.8 24.9 25.0	.08 .12 .15 .17 .19	7.31 5.68 4.98 4.46 4.19	2.22 2.02 2.12 4.42 1.93	51.112 58.586 61.212 61.260 68.724	2 3 3 3	

*See text.

...y Yard, Boston, Mass., under the general direction of Chief Engineer Chas. H. Loring, U. S. N., ...
...sury Department, in the years 1874 and 1875.
...ith the other steamers see official report dated October, 1874.)

13	14	15	16	17	18	19	20	21	22	23	24
AVERAGE MEAN EFFECTIVE PRESSURE IN CYLINDER.	INDICATED HORSE-POWER.	WATER PER HOUR.			PROPORTION OF TOTAL WATER.		WATER PER INDICATED HORSE-POWER PER HOUR.			COAL PER INDICATED HORSE-POWER PER HOUR.	RELATIVE COST OF THE POWER IN FUEL.
		By actual measurement.	Calculated from terminal pressure per Indicator Diagrams.	Condensed to supply the mechanical equivalent of heat for the total work.	Accounted for by terminal pressure per Indicator Diagrams.	Required to supply the mechanical equivalent of heat for total work.	By measurement.	By terminal pressure per Indicator Diagrams.	Per indicated terminal pressure and amount condensed to supply mechanical equivalent of heat for total work.	Calculated from coal by water measurement (Col. 20) and total heat of steam at actual boiler pressure, on a uniform basis of 9263.34 heat units supplied by the combustion of 1 lb. of coal. (Equivalent evaporation, from temperature 209°, 8.5 lbs. water at 70 lbs. pressure; 8.57 lbs. water at 40 lbs. pressure, &c.)	
Lbs.		Lbs.	Lbs.	Lbs.			Lbs.	Lbs.	Lbs.	Lbs.	
S. 29.685 L. 12.725	S. 127.918 Both. 266.547	4900.10	S. 4568.23 L. 3604.00	S. 349.29 L. 460.71	S. .93 L. .74	S. .07 L. .09	**18.38**	S. 17.14 L. 13.52	S. 20.18 L. 16.56	**2.16**	1.000
S. 18.882 L. 12.300	S. 63.717 Both. 168.652	3726.24	S. 3328.51 L. 2857.56	S. 173.56 L. 350.22	S. .89 L. .77	S. .04 L. .09	22.09	S. 19.74 L. 16.94	S. 22.84 L. 19.02	2.57	1.191
34.439	185.872	4434.37	3018.79	543.95	.68	.12	23.86	16.23	19.15	2.86	1.297
37.127	228.077	5501.26	3932.24	671.22	.71	.12	24.12	17.24	20.18	2.84	1.312
37.538	218.972	5234.51	3576.09	641.52	.68	.12	**23.90**	16.33	19.26	**2.81**	1.300
42.028	292.370	7108.44	5420.24	887.09	.76	.12	24.31	18.54	21.57	2.86	1.322
25.583	124.267	3579.15	2341.96	369.23	.65	.10	28.80	18.85	21.82	3.36	1.554
30.665	161.848	4683.19	3019.52	482.06	.64	.10	28.94	18.66	21.63	3.38	1.561
33.838	196.187	6235.93	3988.28	593.25	.64	.10	31.79	20.33	23.35	3.71	1.716
18.521	137.962	3681.74	2648.88	418.68	.72	.11	26.69	19.20	22.23	3.11	1.438
21.447	186.805	5036.83	3871.18	569 58	.77	.11	26.96	20.72	23.77	3.14	1.452
23.525	221.447	5966.83	4442.12	682.08	.74	.11	**26.94**	20.06	23.14	**3.14**	1.450
24.611	242.807	7017.30	5148.68	751.22	.73	.11	28.90	21.20	24.30	3.36	1.556
24.126	234.295	7261.54	5336.16	727.91	.73	.10	30.99	22.77	25.88	3.60	1.665
15.825	86.985	3511.61	2228.49	281.71	.63	.08	40.37	25.62	28.86	4.66	2.155
16.078	90.169	3982.37	2679.04	294.67	.67	.07	44.17	29.71	32.98	5.09	2.356
16.822	95.254	3175.47	2473.80	305.05	.78	.10	33.34	25.97	29.17	3.85	1.780
16.798	97.867	3660.33	3187.99	321.02	.87	.09	37.40	32.57	35.86	4.31	1.995
15.890	89.650	3053.50	2410.07	281.22	.79	.09	34.06	26.88	30.02	3.93	1.817
17.738	102.906	3587.50	2978.93	326.51	.83	.09	34.86	28.95	32.12	4.02	1.861
20.816	122.842	3194.61	2198.09	373.42	.69	.12	26.01	17.89	20.98	3.04	1.406
20.953	127.196	3396.75	2351.39	388.17	.69	.11	26.70	18.49	21.54	3.12	1.442
26.153	182.227	4373.26	3331.86	541.41	.76	.12	24.00	18.28	21.26	2.80	1.296
26.501	182.364	4800.24	3479.41	564.56	.72	.12	26.32	19.12	22.22	3.07	1.420
30.810	236.874	5800.10	4613.68	708.42	.80	.12	24.49	19.48	22.47	2.86	1.321
30.904	236.457	6644.76	5251.60	746.34	.79	.11	28.10	22.21	25.37	3.28	1.515
30.356	219.465	6493.41	5729.68	650.97	.88	.10	29.59	26.11	29.07	3.45	1.596
19.905	121.072	2778.06	2167.33	376.20	.78	.13	22.94	17.90	21.01	2.68	1.240
21.699	137.501	3294.59	2363.43	415.68	.72	.13	24.02	17.23	20.26	2.81	1.298
21.673	136.448	3054.94	2372.37	415.08	.78	.14	22.39	17.39	20.43	2.61	1.209
23.646	163.251	4055.09	2846.41	499.21	.70	.12	24.84	17.44	20.49	2.94	1.362
24.614	166.211	3851.57	2857.89	504.53	.74	.13	23.17	17.19	20.23	2.70	1.251
26.382	185.192	4761.38	3435.08	576.87	.72	.12	25.71	18.55	21.66	3.00	1.387
28.467	213.022	5388.20	4056.68	622.77	.75	.12	25.29	19.04	21.97	2.95	1.363
31.902	255.005	6763.13	5464.44	778.89	.81	.12	26.52	21.43	24.48	3.09	1.430
26.472	169.643	5083.87	4046.48	710.90	.80	.14	29.97	23.85	28.04	3.53	1.631
28.876	204.787	6012.43	5033.63	833.26	.84	.14	29.36	24.58	28.65	3.45	1.596
27.924	189.581	4904.59	4612.61	779.93	.94	.16	25.87	22.24	26.35	3.04	1.408
29.044	212.190	5801.32	5014.05	861.00	.86	.15	27.34	23.63	27.69	3.21	1.486
35.007	297.779	7514.61	5690.00	951.84	.76	.13	25.24	19.11	22.30	2.96	1.371
32.137	258.505	5945.78	4130.64	793.12	.69	.13	23.00	15.98	19.05	2.71	1.251
33.968	284.181	6873.25	5379.80	894.28	.78	.13	24.19	18.93	22.05	2.84	1.313
34.973	289.152	6286.87	4714.94	843.36	.75	.13	21.74	16.31	19.22	2.56	1.183
34.732	286.843	6577.98	4983.19	854.76	.76	.13	22.93	17.37	20.35	2.69	1.245
31.820	255.306	5993.66	3958.45	766.86	.66	.13	23.48	15.50	18.51	2.76	1.278
33.425	282.485	7157.32	4680.75	855.77	.65	.12	25.34	16.57	19.60	2.98	1.377
32.353	268.630	6541.18	4551.90	808.20	.70	.12	**24.35**	16.94	19.95	**2.86**	1.323
25.763	185.090	4632.68	3238.79	574.65	.70	.12	25.03	17.50	20.60	2.95	1.362
30.106	231.440	5501.42	3936.97	708.82	.72	.13	23.77	17.01	20.07	2.79	1.293
34.028	279.570	6120.30	4576.50	828.29	.75	.14	21.89	16.37	19.33	2.57	1.191
34.676	282.929	6786.40	4796.05	842.00	.71	.12	23.99	16.95	19.93	2.82	1.302
33.351	281.649	6208.37	4698.65	838.94	.76	.14	**22.04**	16.68	19.66	**2.59**	1.198
28.083	196.988	4036.32	3087.52	586.14	.76	.15	20.49	15.67	18.65	2.41	1.115
33.631	270.395	5572.58	4520.37	810.22	.81	.15	20.61	16.72	19.71	2.43	1.122
36.455	306.238	6336.42	5051.36	906.69	.80	.14	20.69	16.88	19.84	2.43	1.126
35.157	295.570	6331.15	5360.83	880.76	.85	.14	21.42	18.14	21.12	2.52	1.165
36.896	347.985	7475.24	5978.83	1040.80	.80	.14	21.48	17.18	20.18	2.53	1.168

October, 1875.

CHAS. H. LORING,
Chief Engineer, U. S. N.
CHAS. E. EMERY,
Consulting Engineer, U. S. R. M.

STEAM JACKET NOT IN USE.

							Throttled.
1	7	8	9	10	11	12	13*
2	L	K	J	I	2—H	G	T
3	December 23d.	December 23d.	December 23d.	December 22d.	December 23d.	December 22d.	December 24th.
4	1.7666	1.98334	2.0500	2.100	2.31667	2.16667	2.5666
5	44.75	40.93	43.29	39.43	39.50	37.67	39.00
6	.11424	.13864	.21951	.27090	.32635	.4129	.6911
7	5.91665	5.2109	3.73449	3.16469	2.71733	2.22615	1.40805
8	25.875	26.071	25.888	23.625	25.942	22.708	24.593
9	30.0705	30.0705	30.0705	30.1427	30.0705	30.1427	29.8428
10	14 760	14.760	14.760	14.796	14.760	14.796	14.648
11	43.000	36.000	36.500	41.140	40.285	41.750	36.000
12	70.000	70.000	70.000	62.000	64.143	64.000	73.333
13	37.000	36.000	36.500	36.930	37.000	33.750	35.000
14	85.000	65.000	69.666	83.785	72.000	106.00	79.333
15	115.000	102.500	111.666	128.430	111.143	147.500	130.000
16	103.666	100.710	107.555	132.444	108.000	138.857	122.8128
17	4558.	5264.	6245.	6318.	7787.	7248.	8113.
18	2580.00	2654.1	3046.34	3008.57	3361.3	3345.23	3160.91
19	43.000	44.2353	50.7723	50.1428	56.0216	55.7539	52.6818
20	41.500	38.000	41.0714	37.0469	37.5833	35.5375	30.0937
21	56.260	52.760	55.8314	51.8429	52.3433	50.3335	44.7417
22	10.1767	10.5815	13.0815	13.9858	16.4266	19.1252	21.7417
23	8.0100	8.0458	8.3672	10.8072	8.2600	13.5002	8.2600
24	3.3252	3.4098	3.2313	4.44617	3.7402	5.5245	3.0349
25	11.8333	11.714	11.928	10.953	11.8125	10.3791	11.7005
26	20.8163	20.9526	26.1528	26.5010	30.8104	30.9037	30.3556
27	18.3163	18.4526	23.6528	24.0010	28.3104	28.4037	27.8556
28	24.1415	24.3624	29.3841	30.94717	34.5506	36.4282	33.3905
29	122.842	127.1960	182.2268	182.3639	236.874	236.4568	219.465
30	108.086	112.019	164.8007	165.1600	217.654	217.328	201.390
31	142.461	147.895	204.741	212.959	265.629	278.727	241.406
32	5617.808	6744.57	8979.535	10039.023	13467.956	14474.453	16736.27
33	4537.	5270.	6255.	6292.	7805.	7287.	8147.
34	1.7585	1.9856	2.05322	2.09136	2.32202	2.17832	2.57742
35	3194.61	3396.752	4373.259	4800.24	5800.100	6644.763	6493.413
36							
37							
38	2198.09	2351.386	3331.86	3479.41	4613.68	5251.60	5729.68
39	.688062	.69224	.761873	.724842	.79545	.790339	.882383
40							
41							
42							
43							
44							
45	26.0058	26.7049	23.909	26.3225	24.4860	28.1014	29.5875
46	17.8930	18 4862	18.2842	19.1236	19.4778	22.2096	26.1075
47	29.556	30.3230	26.5357	29.0642	26.6483	30.5749	32.2429
48	22.424	22 9073	21.3599	22.5407	21.8353	23.8397	26.8092
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*See text

STEAM JACKET IN USE.

	14 A	15 MM	16 B	17 NN	18 C	19 D	20 E	21 F
3	December 21st.	December 31st.	December 22d.	December 31st.	December 22d.	December 22d.	December 22d.	December 22d.
4	2.0166	2.0500	2.200	2.21666	2.0333	3.7500	2.0833	2.300
5	45.42	42.79	41.64	43.89	41.33	40.00	36.18	37.40
6	.10545	.1443	.15525	.1716	.22105	.25473	.3775	.41561
7	6.0785	5.0706	4.81955	4.48778	3.71444	3.32423	2.40387	2.2136
8	26.125	26.535	25.6428	26.555	25.8125	24.588	26.363	24.766
9	30.1628	30.669	30.1427	30.669	30.1427	30.1427	30.1427	30.1427
10	14.806	15.054	14.796	15.054	14.796	14.796	14.796	14.796
11	19.6666	13.333	19.000	13.000	22.000	30.800	40.857	41.000
12	69.500	80.000	74.000	75.500	76.500	69.866	65.857	72.333
13	34.416	33.000	35.000	33.000	34.666	36.200	34.000	34.000
14	61.666	60.666	77.000	61.500	80.000	96.666	74.428	85.000
15	98.333	112.000	109.571	115.500	115.000	129.400	111.143	130.33
16	102.500	109.714	106.857	110.22	113.750	123.647	105.818	123.466
17	5363.	5665.	6064.	6691.	6003.	11509.	6816.	8038.
18	2659.34	2763.42	2752.64	3018.49	2952.29	3069.07	3271.68	3494.78
19	44.3223	46.0569	45.876	50.3083	49.2049	51.1511	54.528	58.246
20	43.2083	38.875	39.82142	39.6428	39.9166	37.6153	34.4642	35.5714
21	58.0143	53.9290	54.6174	54.6968	54.7126	52.4113	49.2602	50.3674
22	9.7644	10.4290	10.3332	11.5183	11.6710	13.5460	14.7960	18.8674
23	8.4727	11.4290	8.6532	12.1612	9.7544	11.4307	14.7960	10.5818
24	3.7258	3.370	3.4664	3.8236	3.7553	4.6609	2.8686	4.5063
25	11.333	11.0830	11.6428	12.000	11.500	10.6530	11.500	10.765
26	19.9048	21.6990	21.6730	23.6458	24.6144	26.3818	28.4668	31.9018
27	17.4048	19.1990	19.1730	21.1458	22.1144	23.8818	25.9668	29.4018
28	23.6306	25.0690	25.1394	27.4694	28.3697	31.0427	31.3354	36.4081
29	121.0725	137.3010	136.4482	163.2515	166.2114	185.1921	213.0218	255.0051
30	105.866	121.350	120.700	145.992	149.331	167.543	194.314	235.022
31	143.735	158.452	158.273	189.650	191.570	217.9114	234.488	291.026
32	5618.10	6731.267	6735.70	8974.02	7845.87	17899.316	11228.702	15653.891
33	5378.	5646.	6069.	6680.	6014.	11531.	6818.	8089.
34	2.0223	2.04312	2.20486	2.21302	2.03702	3.75717	2.06394	2.31459
35	2778.064	3294.595	3054.937	4055.09	3851.567	4761.384	5388.198	6763.129
36	516.214	427.766	320.961	416.000	331.653	552.925	300.000	289.82
37	.091884	.065549	.047652	.046356	.0422583	.030908	.026717	.018514
38	2167.33	2363.43	2372.375	2846.41	2857.89	3435.083	4056.68	5464.44
39	.78016	.717365	.776570	.701933	.742006	.721446	.752882	.807975
40								
41								
42								
43								
44								
45	22.9454	24.0218	22.3890	24.8396	23.1727	25.7104	25.2941	26.5215
46	17.9011	17.2324	17.3866	17.4357	17.1943	18.5485	19.0435	21.4287
47	26.2413	27.1496	25.3082	27.7762	25.7924	28.4017	27.7294	28.7706
48	19.3277	20.8211	19.3017	21.3820	20.1052	21.8501	22.9786	23.2389
49								
50								
51								
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62								

Condensing, Without Vacuum.

	Steam Jacket not in use.		Steam Jacket in use.	
1	22	23	24	25
2	Y	X′	ΔΔ	Z′
3	December 26th.	December 28th.	December 27th.	December 28th.
4	2.2000	2.21666	2.05	2.1166
5	70.71	66.21	69.67	67.42
6	.17799	.24041	.19589	.2365
7	4.3702	3.47969	4.07141	3.52467
8	1.0000	1.708	1.000	1.729
9	30.2852	29.980	30.248	29.980
10	14.8660	14.716	14.847	14.716
11	45.000	39.500	40.428	36.000
12	77.333	78.000	74.428	74.625
13	37.000	34.000		
14				
15				
16	121.727	133.38	126.80	134.416
17	6164.	6873.	6085.	6761.
18	2801.82	3100.60	2968.29	3194.17
19	46.697	51.6767	49.4715	5323.62
20	68.8571	64.3964	67.750	64.125
21	83.7237	79.1124	82.5970	78.8410
22	19.2951	21.5017	19.6803	21 0910
23	41.2594	41.8231	44.6386	45.9243
24	14.8660	14.7160	14.8470	14.7160
25				
26	26.4717	28.8763	27.9237	29.0437
27	23.9717	26.3763	25.4237	26.5437
28	41.3377	43.5923	42.7707	43.7697
29	169.6430	204.7868	189.5806	212.1905
30	153.622	187.0570	172.608	193.926
31	264.911	309.1500	290.580	319.703
32	11186.34	13381.85	10054.40	12263.12
33	6165.	6901	6085.	6752.
34	2.20036	2.2257	2.0500	2.1138
35	5083.874	6012.43	4904.592	5801.324
36			287.569	429.25
37			.028582	.035003
38	4046.48	5033.626	4612.61	5014.05
39	.795944	.837203	.940469	.864295
40				
41				
42				
43				
44				
45	29.9681	29.3594	25.8702	27.3402
46	23.8530	24.5798	22.2355	23.6300
47	33.0934	32.1422	28 4147	29.9153
48	19.1909	19.4482	16.8902	18.1460
49				
50				
51				
52				
53				
54				
55				
56				
57				
58				
59				
60				
61				
62				

	Link hauled up.			Jacket not in use. Draining steam chest.		Jacket in use, supplied direct from boiler.	
	Jacket and Independent Cut-off not in use.	Jacket in use. Independent Cut-off in use.	Jacket in use. Independent Cut-off not in use.				
1	26	27	28	29	30*	31	32
2	QQ	SS	RR	N	N′	LL	KK
3	December 31st.	January 1st, '75.	December 31st.	December 23d.	December 23d.	December 31st.	December 31st.
4	1.91666	2.06667	1.95000	2.500	2.0500	1.8666	2.0333
5	63.83	69.64	59.92	69.56	60.36	71.17	67.00
6	.3656	.24268	.38303	.15139	.2000	.15277	.21267
7	2.47017	3.45409	2.37427	4.90515	4.00848	4.8742	3.82617
8	24.660	26.000	25.346	25.950	25.807	25.841	25.357
9	30.669	30.619	30.669	30.0705	30.0705	30.669	30.669
10	15.054	15.029	15.054	14.760	14.760	15.054	15.054
11	4.000	28.333	14.333	40.400	37.555	4.000	6.625
12	65.000	71.666	86.000	64.400	63.333	75.600	74.000
13	33.000	32.000	33.000	33.600	34.000	33.400	32.500
14	83.000	62.666	65.666	69.000	66.000	78.800	75.000
15	141.000	116.333	121.333	114.200	110.555	130.000	132.000
16	132.64	112.25	122.307	109.600	107.230	121.090	126.000
17	7128.	7268.	7131.	9037.	7402.	6548.	7513.
18	3718.96	3516.78	3656.92	3614.80	2610.73	3507.86	3694.92
19	61.9896	58.6129	60.9487	60.2467	60.1789	58.4643	61.582
20	51.8333	55.214	48.5833	67.6875	58.4485	67.5833	63.000
21	66.8873	70.2430	63.6373	82.4475	73.1885	82.6373	78.054
22	19.5540	15.1004	18.8456	15.6662	16.6528	13.9707	15.6908
23	28.2623	25.4575	28.3040	9.1975	10.5256	16.0540	16.9111
24	6.6695	4.9508	5.9949	3.3432	4.0527	4.2353	4.6086
25	10.333	11.857	11.333	10.984	10.9840	11.583	11.071
26	35.0073	32.1374	33.968	34.9726	34.7324	31.8202	33.4253
27	32.5073	29.6374	31.468	32.4726	32.2324	29.3202	30.9253
28	41.6768	37.0882	39.9629	38.3158	38.7851	36.0555	38.4389
29	297.7790	258.5053	284.181	289.1525	286.843	255.306	282.4847
30	276.513	238.396	263.208	268.482	266.196	235.246	261.356
31	354.511	298.328	334.262	316.7935	320.313	289.286	321.432
32	14500.00	12333.590	13421.62	15706.75	13470.28	11118.167	14526.107
33	7176.	7295.	7141.	9031.	7394.	6548.	7499.
34	1.92957	2.07434	1.95273	2.49834	2.0477	1.8666	2.02954
35	7514.614	5945.778	6873.246	6286.874	6577.982	5993.663	7157.325
36	.....	517.500	374.40	415.50	233.50	458.500	301.481
37	.....	.041959	.027895	.026454	.017334	.040981	.020754
38	5690.00	4130.64	5379.80	4714.94	4983.19	3958.50	4680.753
39	.757190	.694718	.782714	.749965	.75754	.66044	.653970
40	.....	.....	.....	.....	.....	.....	.....
41	.....	.....	.....	.....	.....	.....	.....
42	.....	.....	.....	.....	.....	.....	.....
43	.....	.....	.....	.....	.....	.....	.....
44	.....	.....	.....	.....	.....	.....	.....
45	25.2355	23.0006	24.1914	21.7424	22.9324	23.4765	25.3370
46	19.1080	15.9790	18.9350	16.3060	17.3722	15.5046	16.5694
47	27.1763	24.9408	26.1134	23.4163	24.7110	25.4782	27.3853
48	21.1971	19.9303	20.5624	19.8453	20.5361	20.7188	22.2670
49	.....	.....	.....	.....	.....	.....	.....
50	.....	.....	.....	.....	.....	.....	.....
51	.....	.....	.....	.....	.....	.....	.....
52	.....	.....	.....	.....	.....	.....	.....
53	.....	.....	.....	.....	.....	.....	.....
54	.....	.....	.....	.....	.....	.....	.....
55	.....	.....	.....	.....	.....	.....	.....
56	.....	.....	.....	.....	.....	.....	.....
57	.....	.....	.....	.....	.....	.....	.....
58	.....	.....	.....	.....	.....	.....	.....
59	.....	.....	.....	.....	.....	.....	.....
60	.....	.....	.....	.....	.....	.....	.....
61	.....	.....	.....	.....	.....	.....	.....
62	.....	.....	.....	.....	.....	.....	.....

*See text.

STEAM JACKET NOT IN USE.

	Weighing coal.				
1	33	34*	35	36	37*
2	WJ	W	V	M	U
3	December 30th.	December 24th.	December 24th.	December 23d.	December 24th.
4	23.95	2.18333	2.0500	2.0166	1.9833
5	64.05	71.50	68.21	68.50	61.08
6	.17304	.071048	.12327	.15003	.18494
7	4.46074	7.7825	5.63424	4.93605	4.24913
8	25.285	25.245	25.136	25.875	25.769
9	30.326	29.8428	29.8428	30.0705	29.8428
10	14.886	14.648	14.648	14.760	14.648
11	20.909	39.750	46.000	44.250	36.000
12	74.590	67.500	73.666	72.250	66.000
13	34.511	36.000	36.000	37.000	34.625
14	73.404	75.500	75.333	76.250	68.250
15	128.372	119.000	120.333	111.500	112.625
16	123.669	113.500	117.09	109.080	107.583
17	86941.	6858.	6890.	7244.	7075.
18	3630.1	3141.069	3360.99	3592.07	3567.22
19	60.5017	52.3512	56.0162	59.8678	59.4537
20	61.2708	68.7857	66.1428	66.9166	59.3750
21	76.1568	83.4337	80.7908	81.6766	74.0230
22	15.4103	12.4695	14.1480	15.3433	16.2313
23	14.8478	10.5706	10.5766	9.9267	10.5256
24	4.2794	4.5378	4.6605	3.8714	4.036
25	11.256	10.285	10.2850	11.500	10.872
26	32.3535	25.7627	30.1064	34.0276	34.6763
27	29.8535	23.2627	27.6064	31.5276	32.1763
28	36.6329	30.3005	34.7669	37.8990	38.7193
29	268.630	185.090	231.440	279.570	282.929
30	247.872	167.128	212.222	259.029	262.531
31	304.102	217.691	267.267	311.377	315.860
32	155413.0	10088.13	11199.35	12342.613	13469.217
33	86248.	6840.	6842	7244.	7080.
34	23.7591	2.1776	2.0357	2.0166	1.9847
35	6541.18	4632.68	5501.423	6120.304	6786.405
36					
37					
38	4551.90.	3238.79	3936.97	4576.50	4796.05
39	.695883	.699119	.715626	.747758	.706714
40	21580.				
41	901.044				
42	16.3065				
43	21.6089				
44	706.339				
45	24.3501	25.0294	23.7735	21.8919	23.9862
46	16.9374	17.4985	17.0137	16.370	16.9514
47	26.3893	27.7193	29.9230	23.6277	25.8499
48	21.5056	21.2890	20.5840	19.6556	21.4855
49	3.35422				
50	3.63511				
51	2.96238				
52	2.62941				
53	2.8496				
54	2.32224				
55	7.25956				
56	7.30375				
57	8.15687				
58	9 2607				
59	9.20467				
60	10.2798				
61	2.70553				
62	2.43501				

*See text.

STEAM JACKET IN USE.

	Weighing coal.					
1	38	39	40*	41*	42*	43
2	JJ	S	R	Q	JJJ	P
3	Dec. 28th, 29th.	December 27th.	December 27th.	December 27th.	December 28th.	December 27th.
4	23.9833	2.2166	2.0166	2.1166	4.41666	1.9333
5	65.37	71.56	71.79	69.93	68.25	67.21
6	.17108	.079811	.12162	.14818	.17298	.18871
7	4.49763	7.31451	5.68382	4.9787	4.46185	4.18621
8	25.335	25.722	25.409	25.827	24.932	25.035
9	29.974	30.248	30.248	30.248	29.980	30.248
10	14.716	14.847	14.847	14.847	14.716	14.847
11	37.755	43.000	57.500	32.500	48.555	39.500
12	69.380	70.000	65.000	43.333	66.444	75.000
13	35.977	36.000	35.500	35.000	36.000	35.000
14	72.355	66.000	77.500	65.333	75.444	75.250
15	120.454	114 000	122.000	111.333	117.888	120.000
16	119.470	115.110	117.909	113.769	120.000	121.583
17	88552.	6798.	7089.	7774.	16234.	7972.
18	3692.2	3066.76	3515.21	3672.7	3675.62	4123.45
19	61.5366	51.112	58.586	61.212	61.2604	68.7241
20	63.1146	70.1250	70.4642	68.6428	66.9423	65.8928
21	77.8306	84.9720	85.3112	83.4898	81.6583	80.7398
22	15.4729	12.1387	15.5255	16.5970	16.1198	17.4898
23	12.2619	9.9304	10.5256	10.5256	12.2619	10.5256
24	3.9822	3.6007	4.2397	4.0002	4.1530	4.3830
25	11.330	11.250	11.071	11.071	11.330	11.071
26	33.3510	28.0831	33.6306	36.4546	35.1573	36.8965
27	30.8510	25.5831	31.1306	33.9546	32.6573	34.3965
28	37.3332	31.6838	37.8703	40.4548	39.3103	41.2795
29	281.649	196.988	270 395	306.238	295.570	347.985
30	260.536	179.452	250.295	285.236	274.552	324.406
31	315.278	222.245	304.483	339.841	330.484	380.322
32	148863.4	8961.640	11196.82	13450.04	27978.09	14542.00
33	88531.	6809.	7063.	7796.	16243.	8022.
34	23.9778	2.2202	2.0092	2.12266	4.419115	1.94546
35	6208.37	4036.325	5572.583	6336.418	6331.153	7475.245
36	52.35	459.847	407.668	384.342	934.771	453.077
37	.034645	.051313	.036409	.028575	.033411	.03155
38	4698.65	3087.52	4520.37	5051.36	5360.83	5978.83
39	.756824	.764932	.811180	.797195	.846738	.799810
40	20280.					
41	845.587					
42	15.3047					
43	21.6089					
44	662.865					
45	22.0429	20.4901	20.609	20.6912	21.4201	21.4815
46	16.6826	15.6736	16.7176	16.8791	18.1372	17.1813
47	23.8292	22.4925	22.264	22.2146	23.0599	23.0429
48	19.6917	18 1615	18.3017	18.6452	19.1572	19.2007
49	3.00227					
50	3.24556					
51	2.68203					
52	2.35351					
53	2.54423					
54	2.10247					
55	7.342085					
56	7.41792					
57	8.28438					
58	9.36597					
59	9.46271					
60	10.56802					
61	2.4492					
62	2.20429					

*See text.